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THE SCIENTIFIC MONTHLY

MAY, 1945

SANITARY VENTILATION BY RADIANT DISINFECTION*

By WILLIAM FIRTH WELLS

THE lag in sanitary ventilation during a period of rapid development of water purification, milk pasteurization, and pure food administration is a public health paradox. Yet it was quite natural for sanitary interest in ventilation to lag with the decline of infectious diseases formerly attributed to atmospheric miasma, since close proximity of persons breathing indoor atmospheres made direct transfer of contagious disease without a vehicle a possibility. "Why should we not, in the absence of direct evidence as to other modes of infection, assume at once that contact, that is, the more or less direct transfer of infective material from person to persons, is the principal source of contagious disease?" was Chapin's logical query. And in the absence of direct evidence of air transmission, he concluded, "Bacteriology teaches that former ideas in regard to the manner in which diseases may be air-borne are entirely erroneous; that most diseases are not likely to be dust-borne, and they are spray-borne only for two or three feet, a phenomenon which after all resembles contact infection more than it does aerial infection as ordinarily understood."

So dramatic were the triumphs of aseptic surgery and barrier nursing in preventing contact infection in the hospital that residual cross-infections were entered as nursing errors. For even the strictest discipline did not entirely eliminate cross-infection, nor was the "spacing out" required to prevent epidemic spread of meningitis in barracks, or pneumonic plague in Manchuria, within the accepted range of spray-borne droplets, and Chapin conceded that "Tuberculosis is more likely to be air-borne than is any other common disease."

Sir Patrick Laidlaw found it necessary in the study of experimental distemper to house dogs in outside kennels to avoid indoor spread in spite of aseptic precautions. At the Hygienic Laboratory in Washington psittacosis spread to the personnel in a wing housing infected parrots in spite of all precautions to prevent contact. The persistence of contagious diseases became conspicuous with successful sanitary control of infectious intestinal and insect-borne diseases. Attention focussed upon residual respiratory infections gradually impressed upon epidemiologists the impotence of the contact hypothesis to cope with the phenomena of contagion and Admiral Sir Sheldon Dudley concluded, "It is highly probable that diseases with a higher striking distance, such as chicken pox, measles, and some types of the minor respiratory group, may also be propagated to an unknown extent by the more permanent traveling cloud of the smallest droplets as well as by the momentary but heavy short-range jet."

The bacteriological argument that because diseases are spray-borne only for two or three feet they are not likely to be air-borne was refuted by the demonstration that most atomized droplets evaporate before falling the height of a man, leaving tiny nuclear residues suspended on air currents. Virulent organisms were recovered from enclosed

* Sanitary ventilation studies aided in 1935 by the Milton Fund and in 1936 by the Walcott Fund of Harvard University have since been continued at the University of Pennsylvania by grants from the Commonwealth Fund for the study of the prevention and control of air-borne infection.



FIG. 1. DIRECT IRRADIATION
INVISIBLE LIGHT PROMOTES SURGICAL ASEPSIS.

atmospheres hours after atomization, and nuclei breathed into the lung produced disease in experimental animals. Thousands of nose and throat bacteria which, in the winter, can readily be recovered by appropriate techniques from closely ventilated rooms, are expelled in every sneeze. The environmental control of respiratory infections during the season of closed indoor air thus presents a problem in sanitary ventilation.

Ultraviolet light provides an efficient and elegant method for the concurrent disinfection of the indoor air we breathe. Air transparency makes irradiation efficient in large volumes, for the total lengths of paths of rays emitted into an enclosed space, from the source to the point of their extinction, divided by the volume of the space, determines average intensity. The vulnerability to lethal radiation of organisms suspended in dry air is more nearly uniform than to thermal or chemical agents (Table I). In dry air, moreover, organisms are many times more vulnerable than in drinking water, where disinfection has long been practiced; but as air approaches saturation with water vapor, the vulnerability of microorganisms approaches that in aqueous suspension—falling abruptly at a critical range between 60 and 70 per cent relative humidity. It is fortunate that the conditions favorable to air-borne infection—the closing of windows in cold weather—are also those for most efficient radiant disinfection. Between the seasons of abundant window ventilation and dry indoor air, moist weather may, however, reduce efficiency of radiant disinfection.

The conversion, by the mercury Geissler tube, of electrical energy into lethal radiation is also efficient. The yield of the resonance wave band, among the most germicidal rays, makes fluorescent lighting by reconversion of this invisible light into visible light more economical than lighting from incandescent lamps. The opacity of glass to ultraviolet light, however, requires the use of almost perfectly transparent quartz envelopes, or special glasses with high transmission factors to make lethal radiation practically available to the sanitarian.

Certainly no method of disinfecting the air we breathe could be more elegant than the exposure of organisms to an imponderable lethal agent which does not change the air itself. Being independent of the opening and closing of doors or windows, irradiation is self-regulatory, requiring only good design and clean lamps. No special provision is needed to mix the air with light, for radia-

TABLE I

RELATIVE VULNERABILITY TO ULTRAVIOLET RADIATION (2537A) OF INDIVIDUAL CELLS SUSPENDED IN AIR (E. COLI 1.00)
1936–1937
(Harvard University)

Organism	Number of runs	Relative vulnerability
Bacillus subtilis, vegetative	6	1.68
Bacillus subtilis, spore	5	0.22
Bacillus diphtheriae	6	1.16
Bacillus smegmatis	9	0.52
Bacillus prodigiosus	5	1.33
Streptococcus hemolyticus	4	0.97
Streptococcus viridans	13	0.93
Staphylococcus aureus	13	1.35
Staphylococcus albus	5	1.18
Pneumococcus I	2	1.94
Micrococcus catarrhalis	11	1.00
Bacteriophage	5	2.14
Sarcina lutea (computed)	3	0.85
Tubercle bacillus	*	0.84
Influenza virus	*	1.36

* Computed from absolute exposure in animal inhalation experiments at the University of Pennsylvania.

tion can be directed to, or shielded from, chosen places.

The surgeon, following the tradition of Lister, first applied these laboratory disclosures in practical air disinfection to aseptic surgery. His attention was naturally fixed upon the operating site rather than upon the room air, and to obtain the required intensity over the incision, lights were installed close above the heads of the operating team. The elaborate precautions necessary for protection of the personnel against sunburn hampered their freedom of action, but by taking advantage of the principle of reciprocity between number and length of rays, it was soon possible to overcome these disadvantages by the adoption of equally effective installations. Broad beams of light, directed diagonally from suitable reflectors in the corner of the ceiling and the middle of the side wall, crossed above the incision, maintaining equal average intensity through the room and at the incision, and reduced exposure of the operating team (Fig. 1). The loss of radiation by reflection was compensated by the increase in the length of path of the ray. Simple eyeglasses sufficed to give protection against the nearly vertical radiation.

The sedimentation of infected dust particles upon large areas of defenseless tissue during long operations may be serious to patients with low resistance. The number of particles which sediment on a given area within a given time depends upon their settling velocity as well as upon the number suspended in the air. Larger dust particles, which settle more rapidly than the smaller nuclei, are more likely to contain clumps of bacteria; and lethal radiation, depending for its power upon absorption in the thickness of a bacterium, may not penetrate immediately to each organism. To disinfect completely these larger dust particles may require more intense irradiation than is necessary to destroy organisms in the nuclei of expelled droplets. It is fortunate, therefore, that

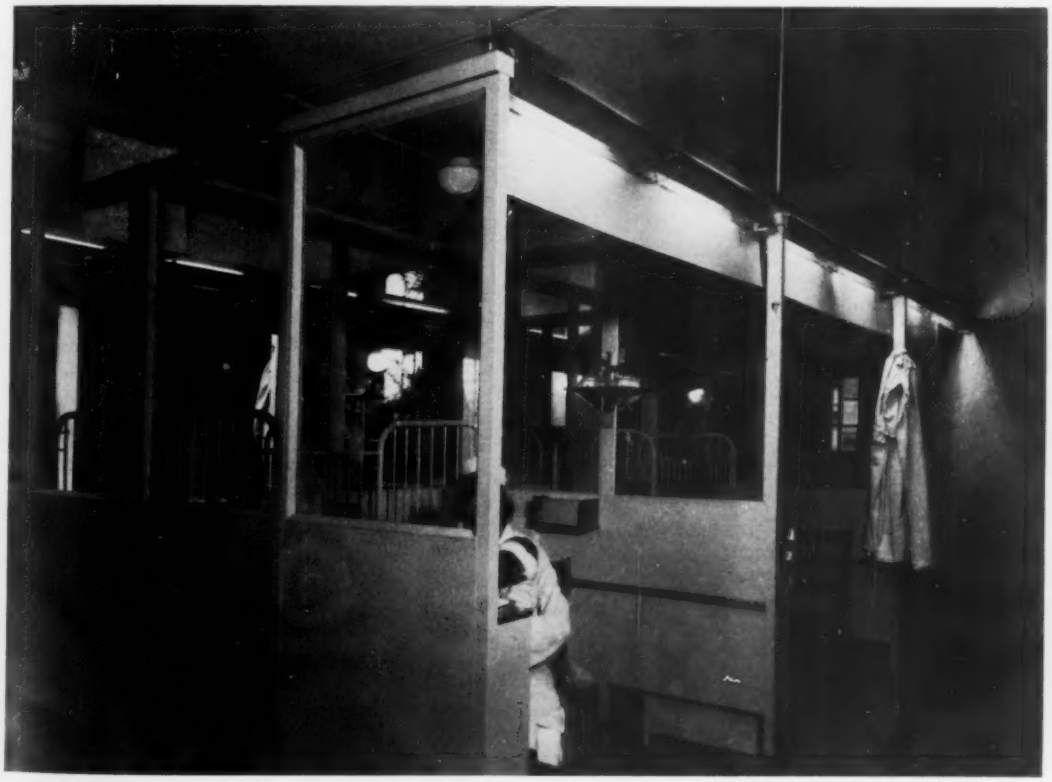


FIG. 2. SEMI-DIRECT IRRADIATION IN A WARD

CURTAINS OF LIGHT IN FRONT OF CUBICLES AND LIGHT CEILINGS ISOLATE PATIENT FROM AIR-BORNE INFECTION.

short duration and rigid discipline permit the efficiency of direct irradiation in the operating room.

A similar problem is met in the protection of burns, but in hospital wards the problem is generally one of preventing respiratory cross-infection. Contagious diseases, so far as is medically possible, are isolated in separate wards, but dust from infected bedding, as well as the nuclei freshly contributed to the air from the respiratory tract, may be wafted to the noses and throats of others. Cubicles have been designed to prevent serious sequelae from such reinfections by the more immediate spread of spray-borne infection. Patients cannot be exposed continuously to direct irradiation, but can be separated by light curtains in front of, and light ceilings above, the cubicles (Fig. 2). Less than one per cent of test organisms in droplet nuclei pass good barriers on ventilating currents. Direct irradiation of the eyes is avoided by placing the fixture so as to clear the heads of the personnel passing through a curtain and the momentary exposure of the skin is negligible, burns being evidence of neglect of ward discipline.

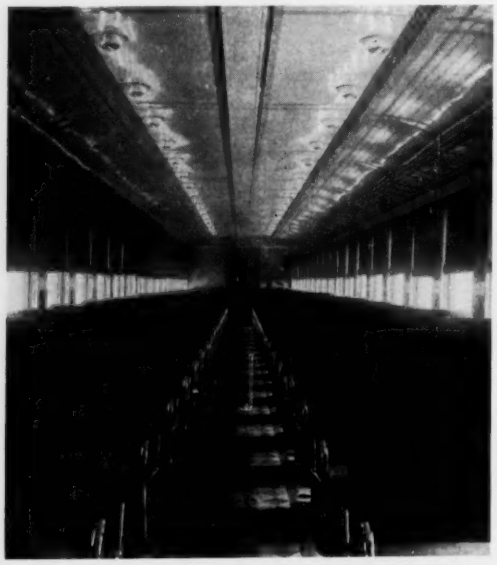


FIG. 3. IRRADIATION OF RECIRCULATED AIR BY LIGHTS IN AIR-CONDITIONING DUCT OF COACH.

Direct irradiation cannot be generally applied outside the hospital, but dilution of air-borne infection by recirculation of irradiated air will be the sanitary equivalent of ventilation with an equal volume of fresh air (Fig. 3). The rapidity of recirculation determines the effectiveness of sanitary ventilation by lights in a duct; if the velocity were infinite the effectiveness would equal that produced by the same amount of irradiation distributed uniformly throughout the room, since the effect of passing air through light is the same as that of passing light through air.

Sanitary ventilation by indirect irradiation depends upon the natural circulation between the occupied and irradiated zones. Effective circulation can be computed from the average death rate of test organisms atomized into the room. Unless wall fixtures (Fig. 4) are specially designed to reflect light horizontally into the middle of the room, central fixtures (Fig. 5) will take fuller advantage of the natural circulation. Radiation losses in reflectors required to give wider distribution of irradiation may be compensated by the longer horizontal rays. Bacteriological measurement has demonstrated that sanitary ventilation rates ten to twenty times standard winter ventilation (but less than a tenth of those obtained by direct irradiation of an operating room) are practically attainable by indirect irradiation of typical schoolrooms.

Control of the dynamic spread of droplet nuclei contagion among aggregations of well persons does not, however, require the rigid measures demanded in the prevention of static dust-borne hospital cross-infection. The fortuitous presence, in the atmosphere, of infected dust depends more upon the activities of persons in a room and the nature of the processes which lift surface accumulations into the air than upon the immediate presence or condition of an infective person. The chance of a coarse particle sedimenting on an unprotected tissue or being entrapped upon the linings of the nose and throat is further limited by the large settling velocity, which removes them quickly from the atmosphere until again stirred up. For dust, air is but a vehicle of transit rather than a more permanent suspending medium.

The pathologic pattern of experimental infection has recently been found to be affected by the size of inhaled particles, and cross-infection of the nose and throat might easily



FIG. 4. INDIRECT IRRADIATION OF SCHOOLROOM BY WALL FIXTURES

result from infected dust particles which, because of their size, do not travel farther into the respiratory tract before lodging. The spread of dust-borne respiratory infections more closely resembles the spread of intestinal infection ingested by the fortuitous contamination of a common source of food or water. Outbreaks of both cease when unnatural chains of parasitic communication independent of the afflicted aggregation are broken.

The aerobiologic conditions which determine the mechanism of spread of air-borne parasites from person to persons sharing enclosed atmospheres and from an exposed aggregation to other aggregations describe, on the other hand, a distinctly different phenomenon. This dynamic mechanism of spread from individuals to aggregations and among aggregations yields an epidemic pattern of spread of air-borne infection which has been characterized since early times as contagion. So long as a contagious case is present in a room, susceptible persons can "catch" the disease by breathing nuclei expelled in coughing, sneezing or even talking, as most nuclei float until removed by ventilation.

To keep warm in cold weather, people gather indoors and indulge in social exchange of friendly parasites. Most persons try to avoid "contact" with contagious cases, but carriers of pathogenic organisms may show no recognizable symptoms or may be infective before symptoms appear. At some time during a winter everyone shares confined atmospheres with infective persons, and in turn exposes others if he becomes infected. Respiratory contagion is thus self-propagating, waxing like fire until the supply of susceptible persons is insufficient to maintain the case rate or until it is interrupted by seasonal changes in conditions of spread, as when summer ventilation dilutes the atmospheric contamination per person. If summer ventilation is sufficient to cause this interruption, it is logical to assume that sanitary ventilation, however practically obtained, would be as effective in the winter when respiratory contagion is at a peak.

This dynamic nature of air-borne contagion may be illustrated by a hypothetical classroom epidemic of measles. Suppose, for instance, the ventilation dilutes the atmospheric infection from a child coming down



FIG. 5. SANITARY VENTILATION OF ROOM
UPPER AIR IRRADIATION BY CENTRAL FIXTURE.

with measles until only one susceptible classmate in twelve catches the disease. Then in a class with six susceptible children exposed to this child we should expect only half a secondary case, or two cases for each four similar rooms. These two cases in the first generation would lead to only one in the next, and the measles would die out in spite of the fact that 21 children remain susceptible. Apparently the dynamic spread of air-borne contagion is possible only above a critical, or threshold, atmospheric density of susceptibles at which contagion spreads endemically and below which it is sporadic.

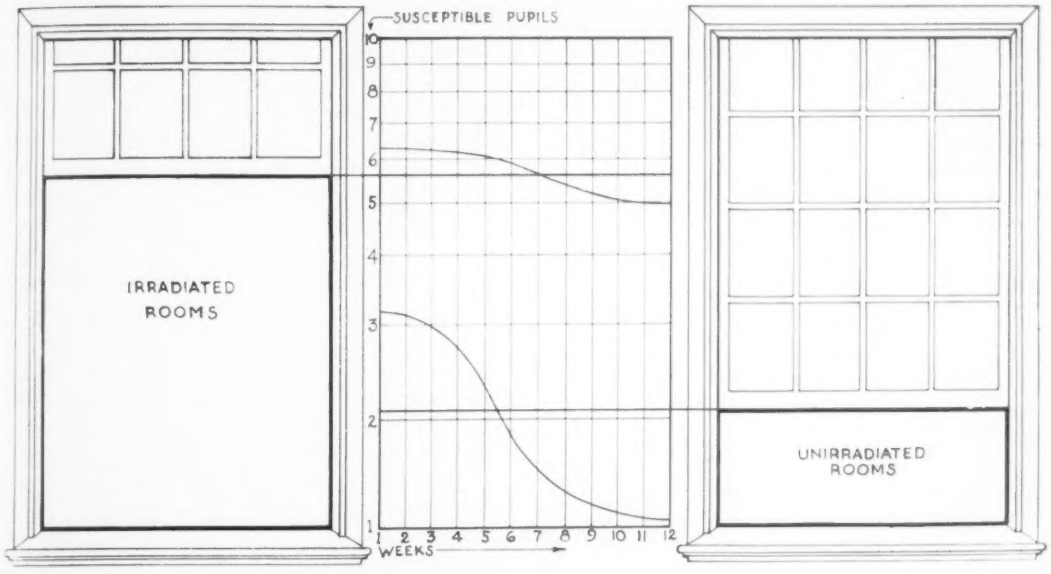
Had there been 24 susceptible children exposed in a classroom the ventilation per susceptible child would have been reduced fourfold because of the fourfold increase in atmospheric concentration of susceptibles. Within two weeks after exposure we should expect two new cases among 23 exposed classmates. Assuming reciprocity between the degree of exposure and the number exposed, we should expect in the second generation four new cases from the 21 pupils still remaining susceptible when exposed to these two new cases; and again in the third generation we should expect by the same ratio five new cases among the 17 remaining susceptible, and again five in the fourth generation, three in the fifth and one in the sixth. The class epidemic would have ended by the seventh generation with only three children remaining susceptible. Thus with a ventilation threshold for 12 susceptible children per classroom, we find among 11 children remaining susceptible in the third generation, five became infected when exposed to five cases. In general, threshold sanitary ventilation is deducible from the number of susceptibles sharing the air supply when an epidemic has reached its peak and begins to decline.

Of course, so simple an example cannot explain so complex an ecological phenomenon as the epidemic spread of contagion involving the behavior of a parasite, the response of a host (both conditioned by innate and acquired characteristics), and intricate modes of transmission between and within human aggregations. Moreover, the existence of an infection and its spread among human aggregations is not always clinically apparent, a fact which impedes the study of epidemic contagion. Rarely can experimentally ideal conditions of spread be realized, even with a single classroom, and consideration of the commerce in contagion through the intricate network of confined atmospheres which constitute a community is based upon the concept of a composite atmosphere. Wilson says, regarding epidemic analysis: "They are all based on the assumption, often tacit, that one is studying a phenomenon in a homogeneous group constantly and homogeneously exposed. This is not the case in a large city or a small state—the epidemic travels around, as we all know, and until the mathematicians can give us a theory which includes propagation in space over time, they cannot expect to have a satisfactory quantitative explanation."

Nevertheless, if threshold sanitary ventilation is the common denominator of the dynamic spread of air-borne contagion, it is possible to approach the problem of air disinfection experimentally, when simple examples of pure parasitism are chosen. In measles, for instance, infection produces a clinical picture. Persons are not naturally resistant to infection, but from it they do acquire lasting immunity. It is therefore possible to determine readily the number of

persons within a group at a given time who are susceptible to this disease. The infection goes through a characteristic incubation period in human beings. This enables us to determine from the date on which the disease becomes clinically visible the approximate date at which effective exposure occurred, and to observe the chain of infections, thus locating the aggregation within which exposure occurred. Clustering of cases within a particular aggregation may further indicate the degree of exposure to a common infected air supply.

Under favorable conditions statistical expression may be given to the probability of contact in air-borne infection. This will depend, at a given moment in time, upon the presence in a given atmosphere of a certain concentration of infective material and a certain concentration of susceptible persons. The concentration of infective material varies according to the rate at which infective organisms are projected into, or removed from, the atmosphere. Other factors remaining uniform, the rate at which infective material is contributed to the atmosphere by infected persons who have reached but not yet passed the infective stage depends largely upon the duration of this stage of the disease and the number of susceptibles infected during this time interval. If an epidemic is primarily air-borne, this means that the rate at which the air becomes infected depends also upon the rate at which susceptibles become infected by the air. The latter, however, depends upon the rate of removal of infective material from the atmosphere by sanitary ventilation. Therefore, the volume of air change in the particular atmosphere per susceptible per minute, or the equivalent removal of infection by disinfection, which for purposes of convenience has been called "atmospheric density of susceptibles," is an important determinant of the rate of spread of air-borne infection.



THRESHOLD SANITARY VENTILATION

THE CENTRAL FIGURES SHOW THE NUMBER OF SCHOOL CHILDREN SUSCEPTIBLE TO MEASLES PER 300 CUBIC FEET OF AIR PER MINUTE IN IRRADIATED AND UNIRRADIATED CLASSROOMS DURING THE 1941 EPIDEMIC.

Now, to study the dynamics of an epidemic of measles we turn to the school, for, in a small community, childhood contagion is focussed in the school; also, we can determine from school records which children are susceptible to, and which are immune from, infection. If classroom aggregations of roughly similar numbers in a school population are exposed for equal periods under similar conditions of ventilation, the atmospheric density of susceptibles varies in proportion to the percentage of susceptibles in each aggregation. If we describe contagion-

spread in terms of percentage susceptibility, the point of inflection marks a threshold density of susceptibles.

The proportion of children in the Germantown Friends School and the Swarthmore Public Schools susceptible to measles during the 1941 epidemic has been plotted on Fig. 6. The proportionate decline in percentage of susceptible pupils in the unirradiated high schools (lower curve) and the irradiated primary schools (upper curve) approximates closely to Wilson's epidemic curve. The points of inflection on these curves mark the proportions of children remaining susceptible when the epidemic peak has been reached, and therefore would indicate the proportions provided with threshold ventilation if the cases resulted from exposure in the same atmosphere.

Actually the curves represent the spread of contagion through the communal groups attending the schools, but since secondary classroom incidence dominated the epidemic among the children in unirradiated rooms this value really indicates threshold ventilation. It appears that for 30 cubic feet of air per minute per pupil (Pennsylvania Code), only one-fifth of the children are provided with threshold sanitary ventilation; indicated by the opening of the window at the right if a wide-open window diagrammatically represents threshold ventilation for ten pupils. The window opening at the left indicates threshold ventilation for 56 per cent of the pupils but, since this resulted from community rather than classroom exposures, it can be assumed that irradiation provided threshold ventilation for all the pupils, as could be indicated by a wide-open window. To provide this ventilation with outside air would be impracticable during cold weather, but an equivalent amount of sanitary ventilation by indirect irradiation has checked the dynamic classroom spread of childhood contagion during the winter in one school for seven years and in two other schools for four years. Meanwhile these ancient diseases have pursued their familiar course in adjoining schools.

Of course irradiation of one atmosphere cannot protect the members of an aggregation against exposure in other atmospheres, and the protection afforded by the lights will become manifest only when exposure in the irradiated atmosphere constitutes a dominant proportion of total exposures, or if secondary incidence can otherwise be identified. The principal reason why measles, mumps, and chicken pox among school children provide such good indices of the hygienic effectiveness of air disinfection is largely that the incubation period enables the identification of secondary classroom incidence with a high degree of probability. Thus was epidemic spread of mumps in irradiated classrooms during the autumn differentiated from the more endemic spread through the community after class secondaries had been checked by cold weather.

Early in the school session, before heating reduced indoor humidity, a case of mumps exposing the third grade of the College Avenue School (Swarthmore) detonated an explosive accumulation of susceptibles. On the second and third generations, synchronous epidemic waves were initiated in the first and second grades, respectively. With onset of cold weather, epidemic classroom spread declined, but waves of decreasing amplitude, fanning out on an ever-widening front, smoldered endemically among the susceptible population of Swarthmore during the remainder of the season.

The endemic harvest in the community, sowed by the school epidemic, seems to indicate a social or communal density of susceptibles analogous to threshold ventilation in a single atmosphere. Without the stimulus of school outbreaks it seems hardly likely that mumps could spread so widely outside of the school in the community of Swarthmore. The spark of a similar episode during the fall of the present year was quenched by the quarantine of the class first exposed, a possibility during the limited critical period of high humidity, even though generally impracticable in school administration.

Moreover, the cessation of epidemic classroom spread is difficult to explain except by a change in the mode of spread, the large number of extra-class cases disproving any change in susceptibility of the children or the virulence of the virus. Sub-threshold sanitary ventilation which would account for the change from epidemic classroom spread to endemic community spread can, however, be

readily explained by the lower efficiency of radiant disinfection during mild, moist, autumn weather.

Where infection confers lasting immunity, the cumulative effect of sanitary ventilation can be determined from school records. Thus the higher average susceptibility of pupils in irradiated schools compared with the normal susceptibility of children in similar unirradiated schools provides independent evidence of the reduction of classroom spread. A reduction of one-third of total cases of measles where half were contracted outside the school corroborates the reduction of two-thirds of the class secondaries, as shown by secondary attack rates. Generally in rural communities where contagious epidemics focus in the school, outside exposures constitute a minority, but in urban communities where exposure outside the classroom is sufficient to maintain the endemic spread of contagion and even in heavily seeded suburban communities, extramural exposure will mask school protection.

Picken has emphasized that, so far as the administrative control of measles is concerned, "any measures for this purpose must have regard to the channels of infection. Children are infected in their homes or at school or at random." And he has pointed out that in rural areas the school plays a relatively greater role in the dissemination of infection than in urban communities. In a rural area, measles spread first in the school and was then carried home to the younger children, the curve of school cases and home cases following the same pattern with a time lag corresponding to the incubation period; in the urban district, on the other hand, opportunity for exposure was not thus limited to the home and the school, random infection playing a greater role. Picken comments: "Clearly it would be difficult to control an epidemic of the latter type by efforts directed at the school. Random infection plays too large a part. On the other hand, the epidemic traced in Chart I indicates that control through schools may be possible."

The interlocking network of aggregations in which the children become infected with childhood contagions is largely restricted to those consisting of children. Multiple exposures to colds, on the other hand, obscure the benefit of preventing single infections. To the network of childhood aggregations in which infection may be spread must be added those shared with adults; and home aggregations especially become relatively more important. Immunity being temporary, a major fraction of the community harbor colds in winter, and this large reservoir of infection makes frequent exposure outside the school inevitable, and identification of secondary incidence within the school impossible. Under such circumstances, incidence is evidence of susceptibility rather than infection.

The complications which arise in a study of the prevention of air-borne infection in a school are thus compounded in the community at large. Sanitary ventilation of isolated atmospheres in an industrial plant, office building, department store, movie, transportation system, or any of the various atmospheres within which people congregate during the winter may individually accomplish comparatively little until air disinfection becomes a general procedure. Not until these different irradiated atmospheres begin to knit, so that a person going about his daily affairs is covered by threshold sanitary ventilation during the winter, will reduction in respiratory contagion fully measure air-borne infection, as water-, food-, and milk-borne intestinal infection and insect-borne infection by blood parasites were evaluated by the general adoption of sanitation. We may reasonably hope that coverage with threshold sanitary ventilation will then bring about the same freedom from respiratory disease in the winter that we now enjoy in the summer. If this proves true, the adaptability of radiant disinfection of air promises a simple and economical method of providing threshold sanitary ventilation to a community.

The environmental control of epidemic air-borne contagion thus reduces in the last analysis to a problem in public health. The tactical problem of providing threshold sanitary ventilation by radiant disinfection may be solved by conversion of lethal irradiation into the hygienic equivalent of ventilation. The distribution of irradiation within enclosed spaces depends upon the length of the rays between the source and the point at

which they disappear from the atmosphere, as determined by their position and direction. Average intensity of irradiation corresponding to the concentration of disinfectant in chemical disinfection, is given by dividing the product of radiant flux and mean ray length by the volume of the enclosed space. This value, divided by the maximum uniform intensity obtainable from the radiation in a cubic space of the same volume or mean ray length divided by the cube root of the volume might be called the efficiency of irradiation.

Maximum disinfection of an enclosed space would be achieved if average intensity of irradiation were uniformly distributed throughout the entire space. In practice, however, it may not be feasible to expose occupants to the intensity required to disinfect. The amount of disinfection throughout the room, for a given average intensity of irradiation, is dependent upon circulation of the bacteria from the occupied through unoccupied zones. The average disinfection actually achieved can be determined by bacteriologic tests, and the fraction that this represents of the maximum, which is theoretically obtainable, can be computed. This fraction might be called the efficiency of disinfection and depends, *inter alia*, upon the efficiency of irradiation.

The principal purpose of bacteriologic tests is to determine the average rate of disposal of significant air-borne organisms from the room by sanitary ventilation. Under special circumstances, as in isolation by light curtains, protection may exceed the average disinfection as defined by these tests. In general, however, the concentration of light in regions away from the occupants will result in less removal of organisms en route from person to person than by average disinfection in the room. The efficiency of irradiation and disinfection may indicate the extent to which protection to the occupants differs from that shown by the average disinfection found by bacteriologic tests.

The interpretation of these sanitary indices is based upon a correlation with epidemiologic indices of contagion spread. It has been found in simplest cases, such as schoolrooms, that with low efficiency of irradiation and disinfection, higher average disinfection would be required to accomplish approximately equal protection against classroom spread of certain childhood contagions. It was therefore proposed that the hygienic rating of disinfection be raised as the indices of irradiation and disinfection efficiencies are increased by good design. The accumulation of epidemiologic experience based upon installations with known sanitary indices should enable the sanitarian to specify threshold sanitary ventilation in engineering terms, to determine by sanitary analysis the hygienic efficiency of particular installations, and to subject practice to laboratory controls.

The resultant communal density of susceptible persons within a network of atmospheres which interlock through social contact may be reduced below a communal or social threshold by covering focal aggregations by threshold sanitary ventilation. The strategy of covering important communication centers of contagion is an administrative problem. Radiant disinfection of air may serve as a useful epidemiological tool for locating these key aggregations by the process of elimination. Because the spread of childhood contagion is largely limited to an age stratum, the school can be shown to be an important vector in the spread of air-borne contagion through rural communities. Perhaps the control of multiple infections could be demonstrated by covering all major aggregations in a small community with threshold sanitary ventilation.

The ultimate goal of sanitation set by Lemuel Shattuck a century ago is to guarantee to members of society the same freedom from communicable disease enjoyed by isolated individuals. Water purification, milk pasteurization, and pure food administration during the present century have added several years to the expectancy of life at birth. Does the control of respiratory infection by sanitary ventilation seem more difficult to sanitary science than the conquest of intestinal and insect-borne parasites seemed at the turn of the century?

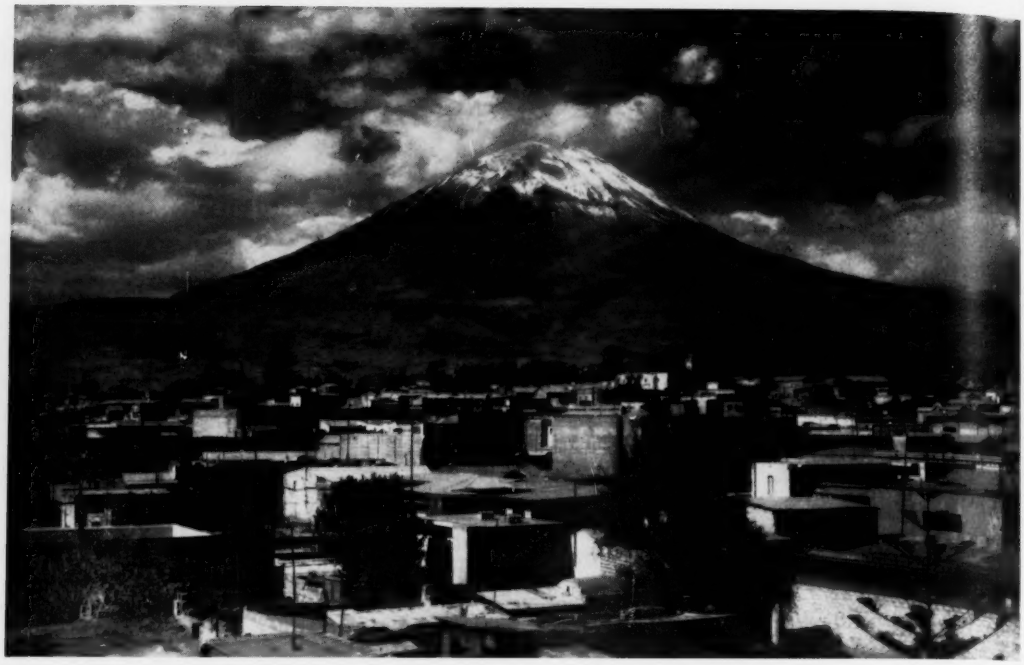
A NATURALIST'S GLIMPSE OF THE ANDES

By KARL P. SCHMIDT

THE great mountain wall of the central Andes extends for almost the whole length of Peru, isolating the desert coastal plain from the great interior valleys and from the vast Amazonian forest beginning at the eastern foot of the mountains. The Andean uplands, broadening out in southern Peru and Bolivia into an interior plateau more than 12,000 feet above the sea, form an American counterpart in physiography and climate to Tibet. Long accessible by rail, these highlands are now reached also by automobile and airplane. The ancient Inca capital of Cuzco, in the heart of the Andes, and the blue waters of Lake Titicaca, at the very center of the plateau region, will long continue to attract a host of tourists. For the naturalist the Andean highland is fascinating for its surprising wealth of animal life adjusted to a bleak climate and rarefied atmosphere. That this region, in spite of its rigorous climatic conditions, has been the center of an agricultural civilization adds an element of human interest; here the Peruvian Indians made their unique contributions to the domestication of animals and to the cultivation of plants. There have been recent expeditions from the agricultural-research organizations of both Great Britain and Russia solely to collect the native varieties of the potato in their original home. Oxford and Harvard Universities have sent expeditions to study the extraordinary physiological adjustments of the Indians to the rarefied atmosphere.

The objectives of a scientific mission from the Chicago Natural History Museum in 1939 were at the level of a broad interest in natural history. It was our purpose to make collections of the animal life of southern Peru as part of our long-continued program of descriptive and geographic studies in the Andean region. My colleague, Colin C. Sanborn, and I, with my son John as assistant trapper and preparator, among other duties in Peru in our 1939 expedition, had a very definite errand in the search for two small mammals, which we promptly began to call the "chocolate mouse" and the "coffee rat." These two distinctive small rodents, one mouse-size, with a chocolate-red coat, and the other as large as a rat, with coffee-colored fur, are so sharply confined to the upper levels of the southern Andes of Peru and to the Bolivian Plateau that they provide veritable index forms for this geographic province. The two species had been discovered by an English collector, at about the turn of the century, in the remote Cailloma Valley, and our chief in the Chicago Natural History Museum, Dr. W. H. Osgood, had often envied the British Museum collection the possession of specimens of these supposedly rare forms, since neither in our museum nor in any other American collection were they available for study. Thus it was that, en route for southern Chile and Tierra del Fuego to complete the Museum's survey of Chile for birds and mammals, we were commissioned to spend a preliminary six months in Peru, and, as the most certain way in which to acquire our two little rodents, to go to the very Cailloma Valley from which they were already known. I hasten to say that our objective was not merely to add these two species to our collection as a stamp collector adds novelties to his album, but also to learn more about their conditions of life, to obtain specimens of the associated species, and especially to extend the knowledge of their geographic distribution. The pursuit of such small game (equally with large) is part of the great and noble effort of museum naturalists to describe the life of the world in accurate geographic terms—a project begun before the time of Linnaeus but still scarcely more than outlined, with the details remaining to be filled in for many parts of the world.

Our collecting in Peru began early in August in the vicinity of the city of Arequipa, which we reached by truck from Lima over a newly-opened highway. We thought it prudent to acclimate ourselves somewhat to higher altitudes before venturing to the 14,000-foot valleys that were our real objective.



MOUNT MISTI OVER THE ROOF TOPS OF AREQUIPA
THE PERFECT CONE OF THIS VOLCANO RISES NEARLY 20,000 FEET HIGH, ONE OF MANY SUCH PEAKS IN PERU.

Arequipa is situated at about 8,000 feet above sea level on an irrigated outwash plain dominated by magnificent snow-capped volcanos —Chachani to the north, with its jungle of peaks left from some stupendous explosion of past ages; the perfect cone of Mount Misti to the northeast, nearly 20,000 feet high; and the fiery red rocks of Pichu Pichu to the east. Convenient collecting stations are available in the vicinity of Arequipa at the various "spas"—Socosani, Yura, and Jesús, whose names are familiar throughout Peru because all three bottle their mineral water for nation-wide distribution. The barrenness of the coastal desert is only a little relieved at Arequipa; the city itself lies among green irrigated fields, but over the wall from such fields the vegetation is still that of a true desert, with sparse, low, thorny bushes, candelabra cactus, and a few hard-stemmed grasses, with much bare ground between the individual plants. The mammals that came to our traps were the big-eared and sand-colored mouse *Phyllotis* and the *cui,* the wild gray guinea pig. We set up a lizard market, as is the custom of naturalists, and found the small boys as expert with slingshot as they are the world over. It was curious to find again the superstition that the little soft-skinned and big-eyed lizards known as geckos are deadly poisonous. No amount of demonstration of the harmlessness of a live gecko could convert our lizard catchers from this baseless fear. When I refused to accept additional specimens unless they were brought carried in the hand, the flow of geckos ended.

Finding ourselves "broken in" after ten days on the slopes of Mount Chachani, at the Yura hot springs, we continued our journey into high altitude via the Southern Railway of Peru. Provided with an invitation from the officers of the Cailloma Mining Company, we were carried comfortably enough to the memorable discomforts of Sumbay, at 13,400 feet, the junction point for the mining trucks that were to take us to the Cailloma Valley. The village is a collection of stone-walled huts and llama corrals, with repair sheds for the heavy trucks. While arranging for our further transportation, we had an effective introduction to the climatic zone in which we were to live for some weeks. Fortunately, for our project, we all three found that we could go about the museum collector's busi-

ness at this altitude, with shotgun and bag of traps, with no great distress, and certainly without the nausea, nosebleed, or the more frightening bleeding from the ears of the *soroche*, the "mountain sickness," which may overtake lowlanders at about this altitude, even when sitting quietly in a railroad coach.

The Peruvian Andes differ strikingly from our North American Rocky Mountains in the absence of a timbered zone. The excessive barrenness of the rocks and sands of the narrow Pacific coastal shelf is a little relieved between 6,000 and 10,000 feet, but this zone is still technically desert, with wide areas of bare ground between the low woody plants, the cacti, and the stiff grasses that form the vegetation. When an altitude with increased precipitation is reached, "timberline" has already been passed. The sequence of zones is low desert, high desert, and, above about 12,000 feet, the better-watered *puna*.

Llamas, absent on the coastal plain, were still a novelty at Arequipa. At Sumbay they dotted the mountain slopes, and llama pack trains were to be seen daily, always with an Indian man or woman attendant. The Indian drovers were invariably engaged in knitting, or in spinning with the Peruvian drop-spindle. The fact that such an activity is essential to those who are at home in the highlands became apparent as we made our own more intimate acquaintance with the rigors of the climate. The most insistent climatic characteristic at these heights is, in fact, the penetrating cold, relieved by the sun for only a few hours during the middle of the day; a chill strikes to one's bones when one enters the shadow of cliff or hill or the artificial shadow of the stone huts. This chill becomes even more pervasive at night, when we found it impossible to keep warm even with our considerable supply of blankets. We promptly acquired an appreciation of the stove as a bedroom accessory; and we were to make the acquaintance of a variety of fuels as characteristic of the highland as its remarkable animal life.



A GECKO (PHYLLODACTYLUS) FROM YURA
HARMLESS, SOFT-SKINNED, BIG-EYED, THESE LIZARDS ARE FEARED AS DEADLY POISONOUS BY NATIVE BOYS.



LIZARD-CATCHERS AT YURA
PERUVIAN BOYS, EXPERT WITH SLINGSHOT, HELPED THE NATURALISTS IN COLLECTING THEIR SPECIMENS.

Next to the llama the most conspicuous addition to our Peruvian animal acquaintances at Sumbay was the mountain vizcacha (of the genus *Lagidium*), a rodent as large as a rabbit but with a long tail carried slightly upcurled at the tip and with a ridge of longer hair along the upper side. This animal is characteristically "petricole," a dweller among rocks. It makes agile leaps from one rock to the next but will take ridiculously long detours to avoid any extended journey over soil. Specimens of the vizcacha were desired in order to correct the classification of a superfluity of supposedly distinct forms named from scattered and inadequate collections. These animals (mostly acquired by means of a .22 caliber rifle)



ROCK SLIDE IN THE CAILLOMA VALLEY, WITH LLAMA CORRAL AT BASE
HOME OF THE "COFFEE RAT" (*Chinchillula*) AND THE LITTLE "CHOCOLATE MOUSE" (*Akodon pulcherrimus*).

proved to be difficult to skin, the more so as our finger's became stiff with cold. When we sat down to skin after the morning's hunt our noses promptly began to drip at a rate that apparently bore some measurable inverse relation to temperature. The flesh of the vizcacha was an item of especial interest. The food at the little inn that sheltered us consisted mainly of the inevitable highland *chupe*, a thin soup made with the bones of a llama or sheep, a little potato, and slices of corn on the cob. Imagine our disgust to find that the Indians of Sumbay refused to cook the good meat from our vizcachas, of which we preserved skins and skeletons, because we did not cut off the tails. It appeared that the tail, especially its tip, is supposed to contain a deadly poison that infects the whole carcass if not cut off immediately when the animal is killed. The herbivore vizcacha and various smaller rodents are preyed upon by the Andean fox and by a highland wild cat. The puma, which ranges along the Andes to Patagonia, was little more than a legend at Sumbay. The abundant hog-nosed skunk is technically also a carnivore, but like its North American relatives it subsists mainly on insects. We caught our first glimpses of the vicuña, the wild relative of the llama, when we climbed the higher slopes.

On the day set for our departure by mine-truck to the Cailloma Valley, we woke to find a six-inch blanket of wet snow from which our mammal traps had to be extracted. Most of them had fortunately been set under overhanging rocks, and our loss of traps was small. The road to Cailloma, rising steeply from Sumbay, soon took us to the world of the *puna* (the paramo of the Colombian Andes). The puna is the high treeless zone, with a vegetation of grasses and stout woody shrubs and of herbaceous plants (especially Compositae), characterized especially by the variety of plants that form rosettes of varying diameter. A striking index plant of the

puna zone is the daisylike *Werneria*, whose large yellow or white flowers are flat on the ground, while the short stems (in the soil) and the rosette of leaves enclosing the flower are densely woolly, as if to protect the plant from the bitter cold. The rosette plants reach their most extreme development in the *yarreta*, a mosslike umbelliferous plant that provides one of the principal fuels of the highland. Where the mountain ridges give way to a level plateau, shallow ponds and lakes are the home of a great variety of waterfowl—ducks and geese, grebes and coots, great numbers of shorebirds, and, most startlingly, flocks of brilliant pink flamingos. Once above 14,000 feet, we had the great pleasure of seeing numerous small droves of vicuñas and even an occasional band of a hundred or more. The vicuña is a graceful animal, with slender legs and erect neck, with a coat of uniform brown wool above and a flag of long white hair on each side of the chest. This animal was in some danger of extermination a generation ago on account of the killing of the newborn young for their pelts and of adults for their fleece.



THE CAILLOMA MINE COUNTRY
ABOVE THE CAILLOMA VALLEY AT 15,000 FEET, THE HABITAT OF MANY DISTINCTIVE ANDEAN MAMMALS.



HABITAT OF THE MOUNTAIN VIZCACHA
THIS LITTLE RABBIT-SIZE RODENT (GENUS *Lagidium*) MAKES ITS HOME AMONG THE ROCKS AT SUMBAY.

After some years of governmental protection, the species now appears to be on the increase.

The third Peruvian representative of the camel tribe now came prominently into view in the landscape. Just as one saw few llamas below 12,000 feet, one sees few alpacas below 14,000. At that altitude the meadows, especially those of the glacier-scoured valley bottoms, with a spongy tundralike mat of vegetation, are dotted with the particolored alpacas as the drier hillsides are with the pasturing llamas. The great abundance of vegetation in the puna zone is plainly conditioned by the abundant water supply; not only is there almost daily precipitation, but the snow-covered slopes above the 16,000-foot snow line insure a year-round supply to the rivulets and larger streams.

On our arrival at the Cailloma Valley we were made welcome at a guest house, maintained by the mining company, which afforded as much comfort as can be expected in the bleak highlands. The dining room, our bedroom, in which we slept on the floor, and the disused bathroom that served as our workshop and laboratory each boasted a small sheet-iron or cast-iron stove. The stone-walled building was situated on a ter-

race above the rocky stream and below the general level of the valley floor. The wide valley bottom was dotted with small ponds and intersected by small rushing brooks whose erosive power is checked by the matted vegetation. Across the main stream below us the south side of the valley rose steeply for some 500 feet, the slope studded with boulders of various sizes. We set our mammal traps beside the large ones (ranging downward from the size of a house), and I could roll aside the small ones in search of lizards, beetles, and other small creatures. The stone walls of the various corrals for llamas and alpacas also proved to be favorable sites for our rodent trapping.

The morning sun was usually sufficient to melt the thin cover of snow that frequently fell during the night or sometimes persisted from the afternon hail and sleet. A sudden afternoon storm came regularly at about three o'clock, and we found it well to avoid its driving hail or at least to have the wind at our backs on our return to the base. There was a hard frost at night, with temperatures ranging down to 14° F. Midday temperature rarely rose to 50°. Small wonder that our thoughts revolved greatly about the problem of fuel supply. While the Indians seem to manage with only a minimum of fire, huddling inside their heavy woolen clothing and blankets, they have a competent knowledge of the available fuels of the puna, which are, with some geographic variation, *yarreta*, llama dung, charcoal, and dried sod. Each of these has its peculiarities as a combustible. The *yarreta* is sufficiently abundant at some localities to be broken up into blocks a foot or two square for transport to Arequipa. It grows in green circular or irregular mounds, sometimes many feet in diameter, two or three feet high. Such masses are pried up from the ground, broken into pieces, and stacked up to dry. The larger pieces break up into wedge-shaped chunks with which a small stove may be fed, and we soon acquired a healthy respect for it. It burns so violently that the stovepipe turns red and the flames pouring out of a short chimney form a fire hazard, while the larger chunks frequently explode and blow open the stove doors and dampers. When *yarreta* is scarce, llama



ANOTHER DENIZEN OF THE HIGH CAILLOMA VALLEY

THIS BIG MALE LIZARD (*Liolaemus multimaculatus*) WAS SUNNING HIMSELF ON A BOULDER AT 15,000 FEET.

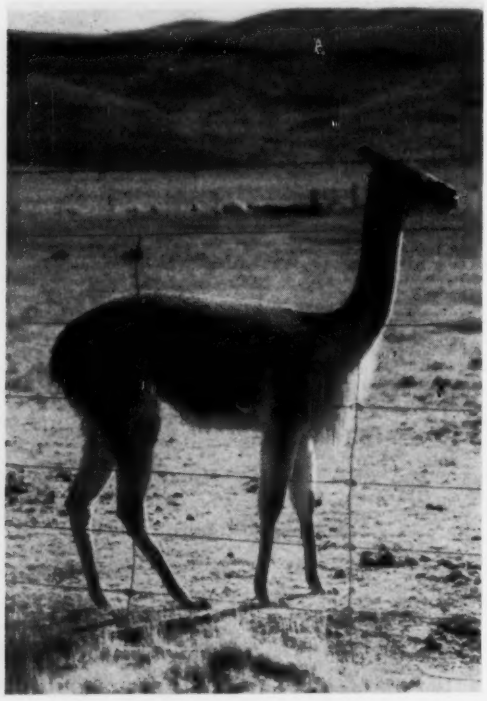


LAKE VILLAFRO, "BIRTHPLACE OF THE AMAZON," 16,000 FEET ABOVE SEA LEVEL

dung is supplied as the most readily available substitute. The llamas and alpacas of the open pasture have the custom, fortunate for the Indian fuel gatherer, of congregating for the night and, even within their night aggregations, of depositing their dung pellets (which are like those of sheep) on piles that often have an astonishingly regular distribution. The wild vicuña has the same habit. The quite odorless llama pellets reached us in large sacks. The management of the stove fired with this fuel was a good deal of an art; if this is once learned, a very satisfactory fire can be made, but there is no danger to the roof from this fuel. We found llama dung to be the principal fuel used at the mine to dry the ore concentrate. Charcoal is the aristocrat of the highland fuels. It is made from the thick roots and stems of the larger bushes of slightly lower levels, found only at rare localities where special conditions permit their continued growth. Sod was not brought to us at Cailloma, but we found it the principal fuel at the village of Junín, where it was to be seen stacked up in roofed piles in the dooryard of every stone house. It proved to be several times harder to keep a fire going with dried sod.

To live in the rarefied atmosphere at 14,500 feet for even a few weeks is an extraordinary physiological experience for a lowlander. Whatever we did had to be done with extreme deliberation. We could walk at a moderate pace; if we climbed the slopes we had to stop for breath at frequent intervals; and time out for breath-catching was necessary after rolling over every few stones. I had an impressive personal lesson as to the closeness of the limits of our physiological capacities. While walking along the flume that carried water to the power plant of the mine below us, I winged a large hawk and saw it run toward the flume. To head it off I sprinted about twenty-five paces to a small bridge of railroad iron that spanned the flume, threw myself down, and caught my hawk as it was carried down to me by the current. At the same moment the blood seemed to pound in waves to my temples, and I fainted away for what must have been a period of some minutes. When I recovered consciousness it took several minutes of careful breathing before I could rise to my feet and again look for my hawk. The indication was plain that a few more steps would have led to a longer and perhaps a permanent

blackout. The fact that every Andean village has a soccer field affords a vivid illustration of the perfected acclimatization of the highland Indians. The barrel chests of these mountain people are evident; they house enlarged hearts and increased lung capacity; and their blood is phenomenally thick with red corpuscles to meet the difficulty of oxygen supply. These Indians do go to lowland plantations to work; but they are said to be much subject there to respiratory diseases and to insist on returning to their native highlands after relatively short periods of lowland service. The ability of the condor to ascend to the greatest Andean heights, much above 20,000 feet, and to descend to sea level in search of carrion at the Pacific strand line affords a natural counterpart, unfortunately with little practical advantage for us, to the great physiological problems set for modern aviation by high-altitude flight.



PERUVIAN VICUÑA

ALSO OF THE CAMEL TRIBE, VICUÑAS LIVE IN SMALL DROVES ON THE HIGH PLAINS AND ARE PROTECTED BY LAW. THIS ONE IS A CAPTIVE AT CHUQUIBAMBILLA.

The higher ridges on both sides of the Cailloma Valley were snow-covered, evidently permanently so. There were patches of snow at 16,000 feet, and I believe this to be very close to the snow line, which varies through only a few hundred feet during the year at this level and latitude. The frogs and toads and lizards and snakes are so much dependent on warmth, and so obviously have their headquarters in the humid tropical zone, that one could not expect any great variety of species in the puna zone. Actually I found only two species of frogs, a single toad, and one kind of lizard in the Cailloma Valley. On my visit to the mine at the head of the valley I found a big male lizard (*Liolaemus multimaculatus*) sunning himself on the top of a boulder at the 15,000-foot level and felt certain that this must be the altitude record for the species. Some days later my son and I climbed to Lake Villafro, whose icy waters are at 16,000 feet, and there again was a *Liolaemus* sunning itself only a few yards from a patch of snow. This lizard proves to be widespread on the highland. It escapes the cold of the night by retiring into deep burrows in the soil. The frogs and the toad and the highland lizard are quite evidently creatures that have become adjusted to the cold, and they escape freezing by retiring into burrows or into the water. The characteristic gelatinous strings of eggs of the toad (*Bufo spinulosus*) were found beneath the ice at Sumbay; and at Cailloma I found the eggs of the large black frog (of the genus *Telmatobius*) attached to the underside of a stone at the edge of the river. This frog is one of the most characteristic creatures of the Andean highland, one or another of its various species being found everywhere from Ecuador to central Chile above 6,000 or 8,000 feet. My principal competitor in the search for lizards was evidently the hog-nosed skunk, which no doubt takes all such lizards as it finds in the course of its digging for insects and insect larvae. Most remarkable of the frogs of the puna zone in Peru is the giant frog of the larger lakes (*Batrachophrynus*), whose distribution is not at all well understood. The common species occurs at Lake Junín, which lies at 14,000 feet, northwest of the village of Junín. This frog is regularly eaten and even comes occasionally to the market in Lima. It is about the size of our common North American

bullfrog, but an average individual would weigh much less, as the whole body is remarkably flattened. The stomachs of the Lake Junín frogs were crammed with aquatic snails. The highland amphibians and reptiles are so completely adjusted to their adverse climatic conditions that they are now limited to the highest inhabitable zone. A single species of snake (*Tachymenis peruvianus*) is abundant at many localities on the 12,000-foot plateau. We found it at Juliaca, and Mr. Sanborn later traced it to an altitude of 15,000 feet.

Much more conspicuous and important to the life of the highland are the birds and mammals. Land birds are not especially remarkable in general; we were especially struck by a large loud-voiced woodpecker that could be compared only with a flicker. Hawks of various species are fairly abundant, and one has an occasional glimpse of the soaring condor. The number of water birds is at first astonishing; one soon sees that both their numbers of individuals and their variety of species are clearly a response to the multitude of Andean lakes. These were evidently produced by glaciation, for the glaciers must have descended several thousand feet below the present level of the snowfields during the relatively recent glacial era. The lakes are formed by the blocking up of the drainage systems by glacial morainic material, exactly as in the lake region of the northern United States and Canada or in the Rocky Mountains. The food conditions in such high altitude lakes reflect the familiar fact that a fauna composed of few species may be represented by very large populations of these few. This is evidently the case with the *Planorbis*-like snails and the few aquatic insects. Even the borax lake at Salinas swarmed with larvae of the brinefly, and accordingly it supported a rich bird life.



THE LLAMA—CAMEL OF THE ANDES

INDIVIDUALS OF THE MOST VARIED COLORS ARE TO BE FOUND IN EVERY HERD. PHOTOGRAPH BY C. C. SANBORN.

There are a few shorebirds, such as sandpipers and phalaropes, that are apparently indistinguishable from the common North American forms; other birds are easily recognizable as of familiar types, like the avocet, grebes, and ducks; and still others are much less familiar, like the Andean goose, various peculiar ducks, and the giant black coot, which is the largest of the coot tribe. Most surprising of all the highland water birds is

the lovely roseate and black flamingo. At a distance this bird appears exactly like the familiar Bahaman species; it is actually so different as to be placed in a distinct genus. Across Lake Huarahuarco, a few miles from our Cailloma base, masses of their pink bodies, raised from the water level by their long legs, appeared like a pink mirage. My son and I made a special trip to this lake, at 15,000 feet, to hunt flamingos, and we hunted them all day in a blinding snowstorm.

It was primarily the mammals that had attracted us to southern Peru, and they were



THE STEMLESS DAISY (WERNERIA)
THIS UNUSUAL PERUVIAN PLANT IS AN INDICATOR OF THE PUNA ZONE. ITS LARGE YELLOW OR WHITE FLOWERS ARE FLAT ON THE GROUND; STEMS IN THE SOIL.

especially interesting because almost every species is limited to the puna zone and to a south Peruvian faunal province. The little "chocolate mouse," named *pulcherrimus* as the handsomest of its genus (*Akodon*), was abundant on the rocky slopes and especially along the stone walls of the llama corrals. We caught the last specimen of our series under the bathtub in our makeshift laboratory. The "coffee rat," with its coffee-colored fur, came to our traps among the larger boulders; its soft fur is referred to in its generic name *Chinchillula,* by way of comparison with the true chinchilla, an animal of the same highland zone, now extinct in most of the Andes. We found a species of the mouse *Phyllotis* and an allied form very similar in appearance neatly avoiding competition, as one was diurnal, the other nocturnal. By climbing the sides of the valley to the 15,000-foot level, we could often get a glimpse of a small band of vicuñas and hear the whinnying cry of the stallion. The vicuña, with its slender limbs and graceful erect neck, looks only remotely like its domesticated relatives, the llama and alpaca. The relationship to the camels is betrayed when the animal breaks into its awkward rockinghorse gallop. It is one of the major privileges of a visit to the highland of Peru to see in the llama and vicuña the living relatives of the North American camels of the middle Tertiary. My son had, in fact, been digging up Miocene camel bones in South Dakota with a paleontological party before he joined our expedition. The preservation of types recently or even anciently extinct in Eurasia and North America, like the camels and tapirs, gives the character of strangeness to the animal and plant life of the southern continents. In a sense, to travel to them is to step into the past in a time-machine.

The great wealth of mammals and birds in the puna contrasts strikingly with the poverty of the desert plain and the lower Andean slopes. Not only are there large populations of individual species, like the mountain vizcacha, the alpaca, and the vicuña, but there is also a great variety of species whose limitation to the bleak climatic zone just below the snow line shows plainly that they are adjusted to the low temperatures and that, indeed, they require them. The existence of a zone of well-watered soil in the highland conditions the increased number and variety of herbaceous plants and grasses; these produce a surplus food supply for the herbivores; while the great populations of the herbivores in their turn afford a surplus available for the carnivores. There is an obvious reason for this wealth of animal life in the richness of the vegetation that serves as their food, here called forth by the perennial water supply. Such a flowering of the fauna in both species and populations suggests a corollary to the principle of natu-



ALPACAS FEEDING ON THE TUNDRALIKE VALLEY FLOOR OF THE CAILLOMA VALLEY

ral selection resulting from "biotic pressure" on animal life as a whole. It is the inevitable result of the forces summed up in this concept that both plant and animal "populations" should expand into any area in which a surplus of food becomes available. It seems evident that the diversification by evolution of plants and animals, whereby they are enabled to pursue food supplies even into unfavorable climates and into obscure and inaccessible niches, is just as much a result of "selection pressure."

The pursuit of surplus food supplies through evolutionary changes that enable living things to reach otherwise and previously unavailable food supplies is self-evident in such vast steps as the invasion of the land by plants, followed by that of animals, in remote geological ages; in the multiplicity of insects that attack every kind of food, including each other, with their sharply defined food habits and special adjustments to special foods; and in such extreme specializations as those of the termite-eating anteater or the nectar-feeding bee. Among the insects attacking the excess of plant foliage the leaf-mining insect larvae, reaching the soft tissue between the surface layers of a plant leaf, seem to be especially safe from enemies; yet insect evolution has supplied special predatory insects that reach even these tiny creatures. The striking adjustments of animals to scavenging form another illustration of such utilization of food supplies, as does the entry of commensal and parasitic animals into the bodies of their hosts. I believe therefore that the wealth of life of the puna zone illustrates an all-pervasive law of nature—a law of evolutionary utilization of surplus food. The correlation between population growth and food supply is the familiar theorem of Malthus. That the diversification of plants and animals proceeds by adjustment to new environments and to special food habits in response to food surpluses is a somewhat parallel evolutionary theorem, which perhaps may be offered as a corollary to the general theory of natural selection.

The rich and peculiar fauna of wild animals by no means exhausts the biological interests of the highlands. Quite as interesting as the wildlife of the Andes is the extraordinary series of domesticated animals and cultivated plants that have their center of development and evidently their origin on the Andean plateau. While we were in Peru there were two expeditions, one from England and one from Russia, collecting native varieties of potato. There are more than

200 named varieties of this indispensable vegetable in the country of its origin, and some of these may be of great importance to the northern countries, since they include frost-resistant strains. There is a standing argument, unsettled as yet, as to whether Indian corn originated as a cultivated plant in Central America or in Peru. Certainly the Peruvian Indians cultivated it long before the dawn of the Inca Empire. Besides these most familiar of the contributions of Peru to the resources of civilization, there is a variety of edible tubers quite unknown elsewhere, like the *oca*, a member of the oxalis family; and a still greater variety of small grains with a general resemblance to our millet. The llama and alpaca have already been mentioned. They must have been domesticated on the highland, from the northernmost stock of the wild guanaco, which still occurs in extreme southern Peru. It has sometimes been thought that these two animals represent separate domestications, the llama of the wild guanaco and the alpaca of the vicuña. This does not appear to me to be at all likely, the divergence between the two domestic races being readily explainable as due to artificial selection for the production of wool in the alpaca and for a general service animal in the llama. The dog of the Incas apparently came with the ancestral Indians from North America (and from Asia) and cannot be counted as especially Peruvian, but a fourth domestic animal is as peculiar to Peru as the llama—the guinea pig. The guinea pig, being neither a pig nor from Guinea, bears one of the strangest of misnomers. It appears to be directly derived from the common wild gray cavy of the highland. We found it abundant from about 8,000 feet at Arequipa to 14,000 feet at Lake Junín. In the village of Junín domestic guinea pigs were abundant in the stone-walled streets—a varicolored lot, some albino, some black, some particolored, mostly short-haired, but with an occasional shaggy individual. As we approached they ran ahead of us, and each ran into the doorway of his proper stone hut.

The fact is that the guinea pigs of Junín were so varied in coloration that only an occasional pure white one or a pure black one could be said to be like any other, while in the wild gray stock of the surrounding hillsides every individual seemed to be exactly like its neighbor. The llamas and alpacas, free in their pastures, present a similar picture of variegation without evident rule—with white and black and brown and particolored and steel and roan individuals. It is evident that there is no selective breeding for any particular color by the Indian owners of the animals; and it is equally apparent that variety of color and color pattern develops without selection. In the droves of wild vicuña, on the other hand, every individual was of exactly the same shade of brown, just as all the wild cavies are gray. The vast combination of environmental forces summed up as selection pressure or biotic pressure has forced animals to become diversified and to adjust themselves to the greatest variety of habitat niches; while once so adjusted the same pressure apparently operates to keep the resultant species uniform. Protection from predatory animals, under domestication, is evidently sufficient to release animals from this environmental pressure. It will be recalled that there is a similar variety of color patterns in our own domestic livestock and that intensive selection is required to produce or to keep the uniform coloration of a special breed. Indeed, I might hesitate to mention so familiar a phenomenon, but I had somehow thought of the familiar laboratory types of guinea pigs as produced by selection; and to find them leading a free life in the stone-walled streets of an Andean village, though it should not have been, was a surprise. The mottled brown-and-white marsupial cuscus of New Guinea is the only wild mammal that I recall in which there is no uniformity of pattern; and in its case, too, somewhat the same principle may apply, as this is an animal for which the peril from predators must be small, since New Guinea entirely lacks carnivores.

My view of the Andes was all too short. It afforded a glimpse of a promised land for further biological survey, in which, employing the new roads, our knowledge of the distribution of animal life in a biotic province of unusual interest might be brought to a high level. For myself, I travel hopefully.

DISCRIMINATIONS IN FOOD SELECTION BY ANIMALS

By WILLIAM A. ALBRECHT

THE discriminating appetites of laboratory animals appear to be manifestations of the body demands for particular nutrients, as was recently demonstrated by Dr. Curt Richter.[1] In his experiments, rats refused to eat sugar or fat when their bodies, operatively modified, could not digest these substances. When they were given increasing quantities of insulin, they ate increasing quantities of the sugar made available to them, for then their bodies could use it. They consumed large amounts of solutions of different calcium salts when their parathyroids, which control the body's use of calcium, were removed.

That the appetites of farm animals are similar physiological manifestations of their nutrition needs is suggested by observations of animal choices of feeds and forages according to fertilizer treatments of the soils on which they were grown, and by the growth behaviors of animals when compelled to subsist on feeds they would of choice refuse. Farmers have reported observing some seemingly uncanny discriminating selections by animals of the same feed plant species, according to certain soil areas within a single field and between different fields.

Chemical analyses of crops giving their constituents, as carbohydrates, proteins, fats, minerals, and vitamins, are insufficient measures of their over-all values for animal growth, for they have been found to depend on the finer differences in the same crop resulting from applications to the soil of limestone, phosphate, potash, or other fertilizers. When these chemicals are added to the first few inches of ground in which crops grow in amounts of only 100 or 200 pounds per acre, as is often done, they are diluted by 2,000,000 pounds of soil. Chemical methods are not sufficiently accurate to detect such small differences in the constituents of the soil, or in the crops that are grown on it, although crops are normally better even with such small additions of suitable fertilizers. But the appetites of animals as shown in selecting their feeds depending on soil treatments with fertilizers are accurate almost to inches in delineating the areas on which different fertilizers have been applied. Free choice of feed by animals, and more rapid animal growth when fed according to their choices, are now being used as refined measures of soil fertility. Heretofore the fertility of soil has been determined by its yields of farm crops per acre, but henceforth it may be done from the nutritive values of the crops produced. Some particular observations of the delicacy of animal appetites in food selections will illustrate the method.

When a new, unfenced roadway was put through a forest in the Ozark Mountains of Missouri, the question arose as to what type of tree could be used for roadside planting without danger of destruction by wild deer. The southern pine was suggested because in the adjoining forests the seedlings of this tree were not taken as browse by the deer. However, when the roadway had been planted with southern pines transplanted from the well-fertilized soils of the forest nursery, the deer that had not been taking this same species in the forest came out to the roadway and completely stripped the fertilized plantings.

Greater consumption by deer of the browse on areas in the forest receiving heavier nitrogen applications has been observed and reported in the Black Rock Forest studies.[2] Other discriminations by wild animals as to quality of vegetation are sufficiently numerous to suggest that there is much to be learned about soil fertility by observing the appetites of wild animals and their selections of feeds according to soil differences.

Domestic animals, too, are very discriminating in their choice of foods, but offerings of herbage of single species only and the confinement of animals by fences prohibit more frequent demonstrations of these abilities. There was wisdom in the husbandman's rec-



By Courtesy W. M. Landess, TVA

FIG. 1. COW CHOSE HER GRASS SO AS TO HAVE A BALANCED RATION

PASTURE GRASSES IN MIXTURES, SUCH AS BLUEGRASS AND WHITE CLOVER, ARE NOT TAKEN AT UNIFORM RATES.

ommendation handed down from times past that pastures should be of mixed herbage to be most efficient.

Sweet clover as pasturage is commonly refused by cattle. It is taken by them only under compulsion and after the other herbage in the fence rows and water courses has been completely consumed. Bluegrass and white clover as a mixture are a time-honored pasture herbage, but even these are taken at different rates at different periods in the grazing season, demonstrating the unerring selections by which the animal balances its diet to become sleek and fat quickly in the spring. Bluegrass growing tall and of a luscious green color in spots where there have been animal urines or droppings is also refused, as is the highly nitrogenous sweet clover. Grass in such fertilized spots continues to grow taller while the surrounding short grass is eaten shorter. Can this be due merely to the animal's fastidious taste?

As a test of this question, a part of the grass area used in a pasture project was fertilized with nitrogen alone to simulate urine addition. This much greener herbage was collected and dried along with that of an untreated plot adjoining. When these two dried harvests were used as the bulk of the diet for rabbits in feeding trials, it was found difficult to maintain them on the grass-hay from soil treated with nitrogen alone. Those on the hay from untreated soil did much better. Sweet clover, too, was fed in a similar manner and the animals "starved to it" to compel its consumption did not survive long enough to suggest other than the starvation interval. These "destructive" aspects of such feeds normally refused by the animal point to the physiological basis for the refusal. They suggest the damaging effects on animal growth of our failure to give heed to the animal's recommendation by its choices of feeds according to their beneficial physiological effects.

Most delicate discriminations by beef cattle have been observed by E. M. Poirot, of the Poirot Farms in Lawrence County, Missouri. His observations included those on animal responses to fertilizer treatments of both the cultivated soils and the virgin prairies of his extensive farm. When barley was seeded for autumn grazing and drilled with 100 pounds per acre of mixed fertilizers, the use of the tractor in wide-

sweeping turns left the corners partly without seed and requiring later attention. These areas were given separate seedings that necessarily included turnings over the areas already treated and thus doubled the rate of fertilizer applications on patches of the soil near each field corner. When beef cattle were turned into these fields to graze the barley in late autumn, they selected and grazed out the areas given the double applications amounting to 200 pounds of fertilizer per acre before they took the crop on the other parts of the field. This discrimination between applications of 100 pounds and 200 pounds of fertilizer by cattle suggests that their physiological response by way of taste is more delicate and refined than most chemical tests or other measures we have been using in judging the feed values of forage.

Co-operative field trials with Mr. Poirot, in 1936, for testing the influence by soil treatments on the native flora of the virgin prairie set the stage for annual demonstrations of extraordinary animal behavior since that year. Surface applications of different fertilizers at rates not to exceed 300 pounds per acre of a single fertilizer were made in the early spring. The combinations of fertilizers were at the heaviest rate of all, but even then at only 600 pounds per acre. All treatments were drilled lightly into the soil. A goodly list of fertilizer rates was used, and a total of five acres at one end of a fenced field of 100 acres was covered with these surface applications. Observations of the changes in flora and samplings of unit areas of herbage for yield and chemical analyses were made during the summer. Later in the summer hay was made. The hay from these five treated acres was mixed with that from twenty acres without soil treatment to make one haystack. Three other haystacks were made in the field, each including the hay from twenty-five acres without soil treatment.

In late November each year more than 200 head of cattle were turned into this field to consume the four haystacks. Water and salt were provided in an adjoining pasture at the end of the row of four haystacks opposite the one containing the hay from the area given soil treatments. The cattle soon showed their keen abilities in selection by daily passing

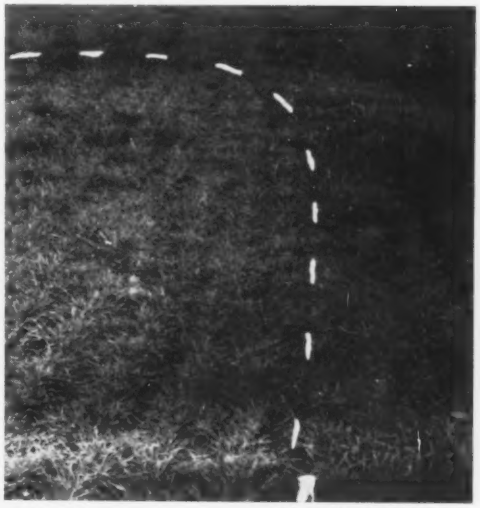


Photo by E. M. Poirot

FIG. 2. CATTLE GRAZING EXPERIMENT
CATTLE CROPPED THE BARLEY MORE CLOSELY (LEFT) WHERE IN DRILLING OUT THE FIELD CORNERS THE FERTILIZER APPLICATION WAS JUST ABOUT DOUBLED.

the three haystacks from the untreated area and going to consume first the stack in which the five acres of hay with soil treatments was mixed with that from the twenty untreated acres.

This 100-acre area has had no soil treatments since 1936. Hay has been made and stacked in similar manner annually since that year. The cattle, too, have behaved similarly each year by demonstrating their first choice of the stack containing hay from the soil given the fertilizer treatments in 1936.

When the stack was first laid down for the eighth demonstration in 1943, it was too small to take the hay from the five acres treated in 1936, and all of the hay in addition from the twenty acres untreated as customarily put into this stack with it. Consequently, a part of the hay from this untreated area was built-on as an extension of the stack. The cattle cut this stack in two at the juncture of these two stackings by consuming first that part which included the five acres formerly treated, and by leaving unconsumed the end made up wholly of untreated hay. They then distributed themselves amongst all the stacks in the field, including this remnant that had no greater lure for them than the untreated hay in the other three stacks.

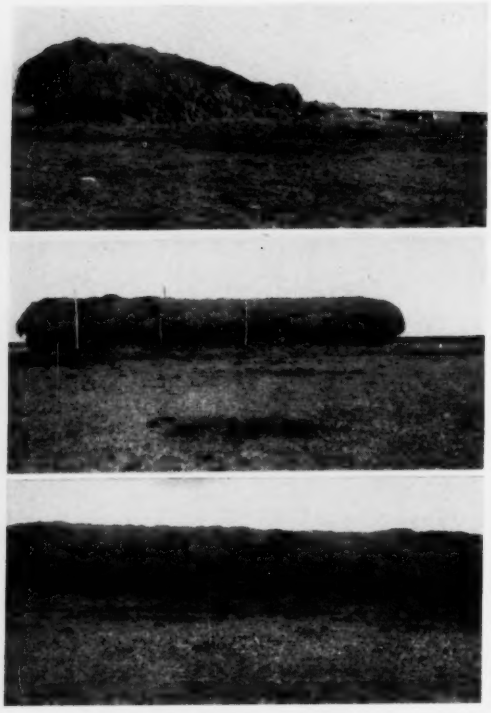


FIG. 3. RESULTS OF EXPERIMENT IN 1943 WITH $\frac{1}{5}$ OF ITS HAY FROM SOIL FERTILIZED IN 1936 END OF TOP HAYSTACK WAS CONSUMED WHILE OTHERS WITH HAY FROM UNTREATED SOIL WERE IGNORED.

In October 1944 when the cattle were turned into the field with the stacks, no frost having come to kill the grass before mid-November, the cattle took to the grass and not to the hay. They grazed persistently on the limited acreage where the soil had once been fertilized. When they finally took to the hay, they failed to select so pronouncedly the stack with a small part of its bulk made up of hay from fertilized land. Evidently the effects of the fertilizer were still recognizable in the grass, but not in the hay when this was diluted in the haystack with unfertilized hay by a ratio of one to five. Unfortunately, there was no stack made solely of fertilized hay to test this question more accurately.

The delicacy of the appetite of the cattle is clearly demonstrated by giving consideration to the following factors in the case. No more than 600 pounds of fertilizer was put on the surface of the soil. It was subjected to an average annual rainfall of 35 inches during eight years. Nine crops of hay have been removed. The treated hay each year was diluted so as to make up only one part in five of the preferred stack. And in the eighth year the animals were still passing by the three stacks from unfertilized land and selecting the fourth. By the ninth year they were still recognizing the fertilizer effects in the grass, but not in the hay mixed with so much from soils without treatment. Surely, in the light of this evidence the animals' choice must be recognized as a refinement in detecting differences in the crop coming by way of the soil that chemistry as yet cannot duplicate.

Hogs, as grain eaters, point out by their selection of food that soil treatments register in the differences in the grain, as was demonstrated in forages by the cattle choices. Mr. Virgil Burk, formerly the county agent of Johnson County, Missouri, reported the remarkable discrimination of hogs in "hogging down" corn on the farm of Mr. Cliff Long. These animals, when turned into a large field, went to its opposite end to take grain first where the soil had previously been limed; and they passed daily through the untreated corn in going to and from the water and protein supplement.

The hog has long been credited with discriminating ability as a balancer of its diet. It was Professor Evvard, of Iowa State College, the creator of the self-feeder idea and observer of the hog as a balancer of its diet, who said, "The pig, if given a chance, will make a hog of itself in less time than you will." This uncanny capacity of the hog to exercise choice was used to demonstrate differences in the quality of corn grown on plots with different soil treatments on Sanborn Field, Columbia, Missouri. Since a number of these adjoining plots, in their crop rotations, were to have corn, it was planted across them, several corn hybrids being chosen for the experiment. This arrangement made it possible to sample the corn according to each hybrid and also for the hogs to select according to each plot with a different soil fertility treatment.

Each hybrid was harvested by its particular hills on each plot. A sample was put into a bag, labeled by plot and by hybrid and put away for storage. The remainder of the

corn was saved separately by plot without hybrid segregation. This balance of the corn was put into self-feeders with the particular hybrid mixture from each plot in a separate compartment, in 100 pound units, to permit easy report of percentage consumption. When the supply in any compartment was low, the corn remaining in each one was weighed, and the arrangement with respect to compartments and plots was changed as each was again filled with corn from a plot with a particular soil treatment. Sufficient grain was available to carry out this weighing and rearranging several times.

It was significantly interesting that, regardless of the distribution of the corn among the different compartments in the self-feeder, there was each time the same order of consumption of the grain relative to the soil treatments. Since the corn consisted of mixtures of hybrid breedings in each feeder compartment, a segregated selection by the hogs according to the various hybrids was impossible. The weights of the animals were not kept, nor was any measure attempted of the greater efficiency in making pork through animal selection. But this greater efficiency was reported for rats by Dr. Curt Richter[1] who demonstrated that when permitted choice of the separate ingredients of a common feed mixture, they made the same gains on less feed than when compelled to take the mixture.



Photo by Virgil Burk

FIG. 4. HOGS CHOSE THE BEST CORN
CHOICE BY HOGS OF CORN GROWN ON TREATED SOIL EXACTLY MARKED OUT THIS AREA AS THEY DAILY ATE IT BEFORE TAKING CORN GROWN ON UNTREATED SOIL.

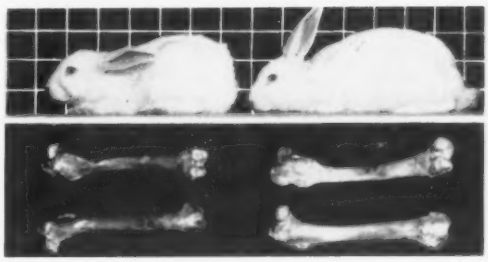


FIG. 5. EFFECT OF DIET ON RABBITS
Left, RABBIT FED HAY FROM UNFERTILIZED SOIL. *Right*, RABBIT FED HAY FROM TREATED SOIL. NOTE DIFFERENCES IN SIZE OF BONES AND APPEARANCE.

As confirmatory of the choice of food by hogs, observations were made of native rats which were not given open access to whole grains because the corn was stored in bags. Samples in small bags of different hybrids and from different plots—though considered carefully stored—were attacked by rats. The bags happened to be piled so that every one was accessible, and the choice of the rats was demonstrated by bags which were found to be cut and those which were left unharmed. Surprising as it may seem, the choice of bags cut by the rats agreed closely by plots and soil treatments with the choices by the hogs. The rats did not distinguish between the hybrids on the same plots within the limited number of choices available in this demonstration. This suggests that the soil on which grain grows, rather than the pedigree of its breeding, is the basic factor that is reflected in the delicacy of the appetite in food selection by animals.

Just what particular chemical compound in the food helps the animal to discriminate and whether it does so by smell, as well as by taste, are still open questions. Very delicate differences are even recognized by chicks, as was demonstrated by Dr. Weston A. Price[3] in testing their ability to discriminate the differences in contents of Vitamin A and "activator X" in butter. Even for butter as an animal physiological product—seemingly far removed from the soil—of

which three grades varying in contents of these two catalytic agents were weighed out daily, put into different positions in the brooder, and weighed back regularly, the chicks selected and ate about two and one-half times as much of the butter high in the "activator X" as of that which was low. The selection was in accordance with the better survival and growth as brought on by these differences in the butter in other tests. This selection by the chicks occurred when neither Dr. Price nor any member of his staff could distinguish between the butters.

The ancient art of agriculture has handed down practices often frowned upon by its youthful science. But when it is now reported that vitamins are generated through microbial activities in the cow's paunch,[4] we may appreciate the soundness of the old practice of hogs following fattening steers to gather the undigested corn. Interdependence of animals, as demonstrated in the importance of providing animal products in the diets for carnivorously inclined pigs and chickens, while cows and sheep are truly herbivorous, suggests the possible use of the animal appetite as a new tool for the assay of feeds, and for the measure of the levels of soil fertility producing them.

That the animal's delicacy in selecting food serves for its better body growth is clearly suggested in work to date. That the soil's contribution of fertility in more generous and in better-balanced amounts is provocative of these choices has not been widely considered. Animal assays of soil fertility to much more refined degrees than are possible by chemical tests are now being used to learn just what treatments a soil needs in order to make its herbage products an efficient forage or hay. In the final analysis, pasture studies must submit to this criterion which the animal itself imposes.

Better body growth is not the only measure by which the products from treated soils are shown to be superior. Better reproduction is another criterion to which soil treatments must cater by way of the feeds as modified by them. The use of rabbits for artificial insemination permitted feeding to one group lespedeza hay grown on soil given phosphate, and to another group the same kind of plant grown on adjoining plots where both lime and phosphate were the soil treatments. After only three weeks the males feeding on the first of these hays had become indifferent to a female in oestrus and were unable to deliver viable semen in regular amounts. Those on the second hay remained readily excitable on the appearance of the female in oestrus and continued efficient in their semen delivery. After the interchange of the hays for the two groups of males, three weeks was a long enough period to reverse their reactions. It is a significant suggestion that the animal's selection of its feeds reaches not only into body functions measured by increase in body mass, but also into those which serve to maintain the species.

More studies will be required before we can use the animal appetites, animal growth, and animal reproduction as refined techniques for the most complete assay of soil fertility. To date, however, animal behaviors have given some very encouraging results to suggest that the student of soils has in the animal itself a detecting instrument, the delicacy of which approaches that of the chemist's spectrograph. When the physiology behind the appetite is more generally understood and when organic differences in the body are connected with, or provocative of, distinct manifestations of the appetite, we shall be in better position to handle our soils for more efficient health and growth of the animals. What this promising approach can do for human health is still an unexplored field. Increasing food problems on a national scale suggest that we should call in all aids to make our soils more efficient as food producers. The delicacy of animal appetites in food selections is one such help that warrants early and wider acceptance.

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CORRIDORS INTO GERMANY

By GRIFFITH TAYLOR

IT HAS been noted many times by military analysts that the geologic and geographic features of Central France determined the outcome of the last Great War as early as September 1914. These important factors in the strategy were the scarps (or cuestas) of the region between Paris and the Vosges. They enabled the Allies to withstand the Germans at the Battle of the Marne, and also at the great siege of Verdun—where the Germans lost half a million men in unavailing attacks on these scarps.

More and more the public is learning to appreciate maps such as Fig. 3, which show the landscape in relief. It is quite possible to draw such maps with great accuracy, but for a rapid survey of the field the maps given in the present article are somewhat generalized. Mountains, plateaus, valleys, rivers and lakes are the chief features in the military landscape; and some knowledge of the way in which these have developed and how they are classified can be gained in a very few minutes by any one who is sufficiently interested to study such maps.

No popular slogan coined in the last few years is so misleading as the one we have all heard, i.e., "The soft Under-Belly of the Reich," if, as one must suppose, it means that the Reich is vulnerable from the south. It is the northeast and northwest which offer the only relatively easy approaches to the Reich, and the reasons for the breadth and flat character of these corridors involves the evolution of the continent of Europe.

The crust of the earth in the vicinity of Europe contains three very resistant areas, called "shields." When the earth's crust contracts and ridges (mountains) are formed, it seems to be because the weaker parts of the crust yield, and are squeezed by these shields much as when a weak sheet of metal (edge on) is squeezed in the jaws of a vise.

There seem to have been three main periods in earth history when mountain-building took place on a large scale, and this is true of North America as well as of Europe. Somewhere about 300 million years ago one of these periods occurred, and it resulted in Europe in the elevation of a huge chain of mountains in the region of Scotland and Norway. Here the weak crust between two shields (as shown at the left in Fig. 1) was squeezed between the North Atlantic Shield and the Russian Shield, and possibly this range rose to heights of 20,000 feet.

Contrary to the oft-repeated phrases of the poets as to the "everlasting hills," science teaches that the hills are very short-lived features of the landscape. Their steep slopes are soon cut down by the rapid rivers, heavy rains, frost, and winds which are so characteristic of mountain climates. It is the plains, and even the rivers, which are long-lived; for some rivers are thought to be several hundred million years old, while every mountain is cut down to a "relic-stump" in the course of 40 or 50 million years (provided it has not been re-elevated by earth movements).

Most of Europe to the south of the huge range squeezed up in this "Caledonian Storm," as it is called, was a sea, in which deep deposits of mud and sand had been laid down for millions of years. About 150 million years after the Caledonian Storm there occurred another period of mountain-building, known as the "Armorican Storm." Now, during several million years, a great range of mountains was raised up between the great resistant Russian Shield and a similar shield to the south in Africa. The results of this storm are shown in the central sketch map of Fig. 1 as a series of mountains extending from western Spain to the south of Russia. By this time the Caledonian Storm mountains were reduced to low plateau-like "stumps," as indicated. In the course of the next 40 million years the same fate befell the mountains of the Armorican Storm. They appear today as a series of relic-stumps or low plateaus along the course of the original mountain chain. The hard rocks of Brittany (known also as Armorica)

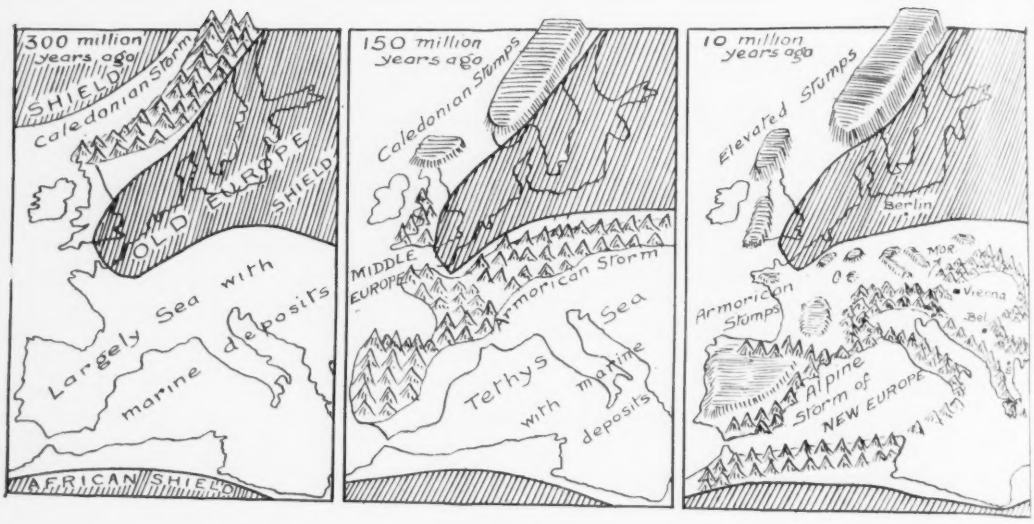


FIG. 1. EVOLUTION OF THE FOUR STRUCTURAL ELEMENTS OF EUROPE

Left, THE RUSSIAN SHIELD (THE BASIS OF "OLD EUROPE") AND THE RISE OF THE NORWEGIAN MOUNTAINS. *Middle*, THE ORIGIN OF THE RELIC-STUMPS WHICH DETERMINE THE BUILD OF GERMANY. *Right*, RISE OF THE ALPS AND MAIN FEATURES OF THE LANDSCAPE TODAY. (FROM *Environment and Nation* BY THE AUTHOR.)

form one such "stump." So also do the plateaus of western Spain, the Cevennes of central France (where the men of the Maquis took refuge), the Ardennes of Belgium, the Vosges, and the several similar "stumps" within the Reich.

At the close of the Tertiary period there occurred the last of the great mountain-building periods. It culminated perhaps about 10 million years ago, but the volcanoes and earthquakes of southern Italy show that mountain-building is still going on there to this day. The results of this Storm are called the "Alpine Storm," since the best-known elevations in this series are the Alps. But many other high mountains—in fact almost all the high mountains of today—belong to this Storm. In Europe, as may be seen in the right-hand map (Fig. 1), we find the Pyrenees, Apennines, Dinaric and Balkan Mountains, as well as the Carpathians and Caucasus to the northeast. It will be seen that this Alpine Storm affected the weak deposits laid down in the "ancestor" of the Mediterranean Sea, which is known as the "Tethys Sea." Thus the summits of the Alps originally consisted of the rather late formations laid down in the sea, but these higher portions have already been washed into the adjacent rivers and seas by the ordinary processes of rock weathering.

It is the last map of the three shown in Fig. 1 that shows in a somewhat general fashion the topography of Germany. The northern portion around Berlin is a vast plain, and this seems to be due to the presence of the Russian Shield (a long way below the surface), which has buttressed this part of the continent, and preserved it from being folded by the forces which buckled up the weaker marine deposits to the south. For this reason also, the invaluable coal deposits, laid down over this buried shield, have not been eroded or so much disturbed as in other parts of Europe. These two facts beyond all others—the presence of wide agricultural plains, and of level beds of rich coal—have made possible military power in Germany.

In Fig. 2 the central portion of the continent is shown on a larger scale. Here again the edge of the submerged Russian Shield (SH) is suggested, while the difference between the high mountains of the last Alpine Storm, and the much lower, flattish stumps of the "young" much earlier Armorican Storm is clearly brought out. (The high rugged mountains are ruled, the lower "stumps" are dotted.) Generalizing somewhat, we can see that there is only one main corridor through the young mountains of the Alpine Storm to the south of the Reich, and that is the "Vienna Gate." It seems

probable that the Danube River is far older than the Alps, and has continued to cut its course. The same thing happened in a more striking fashion near Belgrade, where the Kazan Gorge, only a few hundred yards wide, shows how the Danube kept cutting its valley as the Carpathians seemed likely to bar its course.

The only notable pass through the Alps below the tree-line is the Brenner Pass at 4,500 feet elevation. Almost all the others are 2,000 feet higher. But the Brenner Pass is merely the culmination of a glacier-cut gorge that is over a hundred miles long. Such a corridor is of course easily defended by a small force against very much greater attacking forces, and in the last World War the Austrians made no progress of note against the Italians in this region.

The high young mountains of the Alps just enter the southern margin of the Reich. Hitler's refuge at Berchtesgaden is precisely in this extreme northern edge of the high Alps, not far from the northern end of the Brenner Corridor. Between the young mountains and the relic-stumps to the north is a broad downfold of the crust, which is occupied by the Upper Danube (Fig. 3). This offers an easy route from east to west, say from Vienna to Switzerland, but does not help much in the penetration of Germany proper. North and west of this downfold we see six or eight of the relic-stumps, which today appear as oval areas of moderately high land, though usually mostly below 2,000 feet. They are flattish, and generally forested over most of the surface. Thus they differ markedly from the young mountains, which are rugged and offer insuperable difficulties to travel—except along narrow river or glacier-cut valleys.

Obviously there are many ways to approach Berlin through or near this series of relic-stumps. About a dozen of such corridors are indicated on the simplified chart in Fig. 2. They are numbered somewhat in the order of suitability for attack, though of course only the topographic factor is considered here. No account is taken of the distance from Allied arsenals and supplies.

Before considering the "order of precedence" of these corridors of attack, it will be advantageous to consider briefly the last map, shown in Fig. 3. Here some of the minor details of the topography are charted, and these are especially important in the Northern Plain. Let us consider the course of the Rhine, which is one of the best rivers in the world to use in illustration of river evolution. It rises in the heart of the Alps near the St. Gotthard Pass, and flows down a steep valley until it reaches the "Downfold," where the latter has not yet been filled

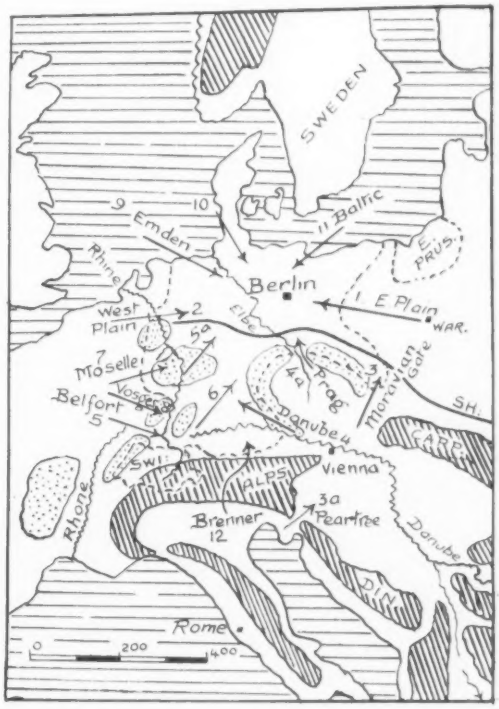


FIG. 2. MAIN CORRIDORS OF ATTACK

THE NUMBERS SUGGEST THE ORDER OF IMPORTANCE OF THE CORRIDORS SHOWN. THE OLD RELIC-STUMPS ARE DOTTED AND THE HIGH YOUNG MOUNTAINS ARE RULED.

level with debris washed down from the adjacent hills. Hence a large lake has formed in this hollow—called Lake Constance. From this the Rhine flows along the Downfold to the west in a broad trough which is quite open to attack from south Germany.

At Basel the Rhine turns north, and here it enters the Reich in the straight section north and south of Strasbourg. This is a valley about 160 miles long and about 20 miles wide. It has a flat floor and steep straight sides—so that indeed it resembles an open grave. This Middle Rhine valley is

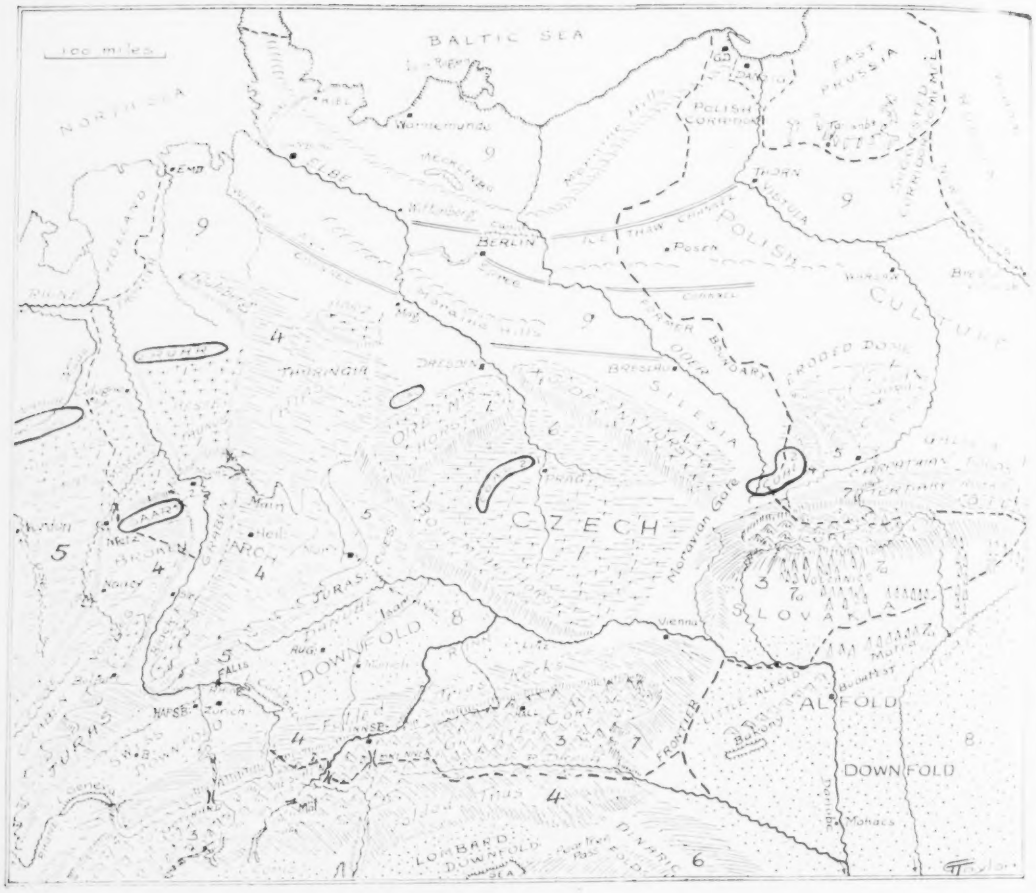


FIG. 3. MODEL OF CENTRAL EUROPE TO SHOW THE STRUCTURE

OLD RELIC-STUMPS ARE NUMBERED 1 AND FORM BELT ACROSS MIDDLE OF MAP. THE ANCIENT GRANITES IN THE CORE OF THE ALPS ARE 3. YOUNGER FORMATIONS, 4 AND 5, FORM PART OF THE BROKEN ARCH, WHOSE RIDGE HAS SUBSIDED TO FORM THE RHINE GRABEN. IN THE NORTHERN PLAIN THE CHIEF FEATURES ARE THE MORAINE RIDGES AND THE ICE-THAW CHANNELS (FROM *Environment and Nation* BY THE AUTHOR.)

what the geographer calls a *Graben,* which is a German word allied in meaning to "grave." Here an elongated block of the earth's crust has subsided to form the graben, and the Rhine has naturally taken advantage of this vast depression in the crust. The Rhine Graben is buttressed by two relic-stumps which already are of profound significance in the war. On the west is the "stump" called the Vosges, on the east is the similar "Black Forest." The Siegfried Line is at the top of the scarp on the east side of this graben, which obviously was a strong line of defense for the Reich.

At the end of the graben near Mainz the Rhine changes its character, and for 60 miles on its course to Bonn runs through the famous Rhine Gorge (Fig. 3). Here it is a narrow steep-sided valley which is of relatively recent origin. In fact we believe that the gorge has been cut out by the Rhine as the hard rocks of the relic-stumps on each side were slowly elevated above sea level. This slow elevation of the stumps *en masse* occurred during the Alpine Storm, but the Ardennes and Hesse "stumps" only rose about 2,000 feet while the "young" Alps were being folded up to 20,000 feet.

To the north of Bonn near Cologne the Rhine reaches the great Northern Plain. Here it spreads out to form a delta composed of the silts it has brought down from the

high Alps to the south. Much of Holland is as truly a delta country as is the famous region in the north of Egypt. Here the river is broad and rather sluggish, while the banks become lower and lower until near its mouth some of the land is now below sea level. Much of this sunken country was once much higher than it is now, even in Roman times; and it has been gradually sinking for the last two millenia.

Let us return to the Rhine Graben for a moment. It belongs to a broader structure in South Germany which is labeled as a "Broken Arch." The rocky formations dip down on each side from the graben, as is clearly shown in Fig. 3. The peculiar windings of the largest tributary of the Rhine (the Main) are in large part determined by the dip of the sloping layers which build up the east side of this arch.

Finally, let us glance at the very interesting features of the Northern Plain, which are bound to affect strategy very greatly, as indeed they did in the last Great War in East Prussia. In Fig. 3 the Plains are seen to be crossed by several ridges of glacial debris of the type called *Moraines*. These are simply material dumped at the front of the great ice-cap which formerly extended south from Polar lands, and covered much of Germany. Between these curved moraines are shallow valleys which are labeled "Ice-thaw Channels" on Fig. 3. They are valleys cut by the huge temporary rivers which flowed to the northwest along the fronts of the ice-cap, as the latter halted at times in its gradual retreat from south to north.

Roads, railways, and canals take advantage of these broad shallow valleys, as they do in the United States and Canada. The city of Berlin is built on piles of glacial debris dumped in the middle of such a broad "Ice-thaw Channel."

In conclusion I will try to arrange the dozen corridors leading to Berlin (Fig. 2) in the order of (topographic) advantage to the attacking Allies. The broadest and best —as offering most room for manoeuvre—is obviously the approach from Warsaw (Route 1). Then I would place the Western Plains Corridor just described (Route 2). The third line of entry is the famous Moravian Gate between the relic-stumps which enclose Bohemia and the Carpathian Young Mountains to the east. This has been used by armies throughout the history of Europe, and offers the easiest outlet for the Russians after they have captured Budapest and Vienna. It will bring them into the broad valley of the Oder, which in turn leads by easy grades into the Northern Plain and to Berlin. The alternative corridor up the Danube to Munich and the Middle Rhine does not offer such a good route, since the slopes and scarps of the "Broken Arch" (already described) have to be surmounted before the Northern Plains are reached. A route (alternative to the Brenner) from the Mediterranean is by the Pear-tree Pass behind Trieste. This is relatively low (2,500 feet), and has often been used by armies to turn the flank of the belt of young mountains of Austria. But it is not favorable for the development of modern large armies.

QUANTITATIVE SCIENCE WITHOUT MEASUREMENT: THE PHYSICS OF ARISTOTLE AND ARCHIMEDES

By CARL B. BOYER

THE history of science in antiquity covers a period of some thousand years, but the lifetimes of the two greatest individual contributors fell within about a century of each other. One of these two men was the greatest biologist of all times, the other the greatest of mathematicians; but both of them contributed, apparently quite independently of each other, to the related field of physics. The achievements here made by Archimedes are familiar even to the casual student, but those of his predecessor in greatness somehow have been neglected. It may therefore be well to give some indication of the place of Aristotle in quantitative physical science.

The development of ancient science is difficult to reconstruct because of the loss of early manuscripts. Works composed before the time of Plato have disappeared almost completely, and many treatises of later centuries have failed to survive. The preeminence of Aristotle and Archimedes has helped to preserve much, but by no means all, of what they wrote. Their contributions to optics, for instance, are still missing. In view of this situation, any final judgment on ancient science necessarily must be suspended.

The origin of physics (insofar as any branch of science may be said to have *an* origin) is largely a matter of speculation—or at least of definition. The oldest law may well be the principle of the lever, but the source of this is unknown. The operation of this law undoubtedly had been observed at a primitive level of civilization, long before it was clearly expressed. It is commonly thought that the quantitative formulation first appeared with Archimedes, but in reality it is at least a century older. In the Aristotelian *Mechanica* one reads:

> As the weight moved is to the weight moving it, so, inversely, is the length of the arm bearing the weight to the length of the arm nearer to the power. (*Mechanica* 3: 850.)[1]

This formulation compares favorably with that of Archimedes:

> Two magnitudes, whether commensurable or incommensurable, balance at distances reciprocally proportional to the magnitudes. (*On the equilibrium of planes* I, props. 6 and 7.)[2]

It is not to be inferred that the Aristotelian statement on the lever represents necessarily the first knowledge of this principle. The treatises of Aristotle resemble the *Elements* of Euclid in that they drew freely from works, since lost, of their predecessors. Nevertheless, until further evidence is disclosed, the earliest formulation should be ascribed to Aristotle, although it was Archimedes who supplemented this with a mathematical demonstration.

In the works of Aristotle one finds also, as Galileo pointed out, the principle of virtual velocities:

> . . . Therefore by the same weight the end of the balance must necessarily be moved quicker in proportion as it is more distant from the cord. (*Mechanica* 1: 849b.)

Further on we read that

> The same power moves the same weight more easily and quickly the further away the fulcrum is. (*Mechanica* 6: 851b.)

In another place we are told:

> If a given force moves something in a certain time, a greater force will do so in a lesser time, but still a definite time, in inverse proportion. (*Physica* VIII. 10: 266b.)

The related principles of virtual and statical moment likewise are given expression by Aristotle:

> The further one is from the fulcrum, the more easily will one raise the weight. . . . So with the exertion of the same force the motive weight will change its position more than the weight which it moves, because it is further from the fulcrum. (*Mechanica* 3: 850b.)

Aristotle appears to have recognized the operation of this principle in connection with systems of pulleys (*Mechanica* 18: 853a–b),

but his language here is confused. However, the equivalence of the two principles—of virtual speeds and virtual work—is brought out in a further passage:

> The smaller and lighter a body is, the further will a given force move it . . . for the relative speeds of two bodies will be in inverse ratio to their respective sizes. (*De caelo* III. 2: 301b.)

The principle of statical moments appears clearly in the answer to the question as to why it is more difficult to carry a long plank of wood on the shoulder if one holds it at the end than if it is held in the middle, though the weight is the same in the two cases:

> The reason is that, if one lifts it in the middle, the two ends always lighten one another, and one side lifts the other up. (*Mechanica* 26: 857a.)

The introduction of the concept of center of gravity customarily is ascribed to Archimedes, but the general notion must be older. Aristotle implies some such idea in passages like the following:

> If, then, a weight many times that of the earth were added to one hemisphere, the centre of the earth and of the whole will no longer be coincident. (*De caelo* II. 14: 297a.)

Although Archimedes in his extant works nowhere defines the center of gravity, it is to him rather than Aristotle that we owe the precise quantitative elaboration of the concept. He made it fundamental in his statics, and in essence he derived the law of the lever from the idea of the center of gravity, rather than conversely as is now ordinarily the case. Postulates and propositions on levers and on centers of gravity are mingled in an exposition in which Archimedes demonstrated the power both of mathematics and of his own unrivaled genius by determining with faultless rigor the centroids of figures, such as the triangle and the trapezium, and paraboloidal and spherical segments. These propositions, involving as they do methods equivalent to the calculus, are among the most glorious of all the Greek contributions to science and mathematics.

There is another elementary law of quantitative physics which was known to Aristotle but is sometimes attributed to Euclid or to Archimedes. The optical law of reflection is not explicitly expressed in the extant works of Aristotle, but it is clear from several passages that he was quite familiar with it. A lost treatise on optics is sometimes ascribed to him and it may be that the law was formally given in this. At any rate, Aristotle frequently alludes to analogies between sound and light, and in connection with the formation of echoes he specifically noted that reflection "takes place at the same angle" (*Problemata* XI. 23: 901b. Cf. 51: 904b). In another passage optical reflection is compared to a mechanical rebound, in which again the equality of angles is repeatedly mentioned:

> Now every object rebounds at similar angles, because it is travelling to the point to which it is carried by the impetus which was imparted by the person who threw it. . . . As then in a mirror the image appears at the end of the line along which the sight travels, so the opposite occurs in moving objects, for they are repelled at an angle of the same magnitude as the angle at the apex . . . , and in these circumstances it is clear that moving objects must rebound at similar angles. (*Problemata* XVI. 13: 915b. Cf. 3–4: 913b.)

Here the author probably has in mind the Platonic doctrine of visual rays emanating from the eye. The visual ray proceeds to the mirror, at which point it meets the ray of light from the object. Both rays therefore travel toward the mirror, whereas in the case of a rebounding object one motion is toward the wall while the other is away from it. In this sense, then, the behavior in the mechanical situation is opposite to that in the optical reflection; but the definite implication is that the cases are alike in other respects, namely, in the rectilinearity of the motions and in the equality of the angles.

The idea of density is widely attributed to Archimedes, but this, too, is clearly expressed in the works of Aristotle:

> Dense differs from rare in containing more matter in the same cubic area. (*De caelo* III. 1: 299b.)

This concept would appear to have arisen somewhat earlier, for Aristotle says that although Anaxagoras and Empedocles had not tried to analyze light and heavy, yet his own predecessors had dealt with "the relative heaviness and lightness of things possessing weight." (*De caelo* IV. 1: 308–309.) Aristotle and his students were aware of some simple facts about density. Galileo[3] attributed to Aristotle the crude quantitative statement that water is ten times as heavy as air. The Peripatetics recognized that

fresh water is less dense than salt water, and that "dense water finds a lower level than water which is not [so] dense." (*De plantis* II. 2: 824a.) It is possible that at that time densities were determined by the method of displacements, for Aristotle knew that

> If one puts a cube in water, an amount of water equal to the cube will be displaced. (*Physica* IV. 8: 216a.)

There is no indication, however, that he was familiar with the great Archimedean principle, the quantitative law of buoyancy. In fact, Aristotle incorrectly ascribed the greater buoyancy of salt over fresh water as due to the lifting effect of salt particles rather than to the increased fluid density. (*De plantis* II. 2: 824a.) The greater ease with which one swims in salt water is ascribed similarly to the fact that it has more body than fresh water and hence, being thicker, offers more resistance to pressure. (*Problemata* XXIII. 13: 933a.) Such statements fall far short of the magnificent quantitative discovery of Archimedes:

> Any solid lighter than a fluid will, if placed in the fluid, be so far immersed that the weight of the solid will be equal to the weight of the fluid displaced.
>
> A solid heavier than a fluid will, if placed in it, descend to the bottom of the fluid, and the solid will, when weighed in the fluid, be lighter than its true weight by the weight of the fluid displaced. (*On floating bodies* I, props. 5 and 7.)

In hydrostatics there is nothing in the works of Aristotle to compare with the brilliant mathematical propositions of Archimedes on the conditions of equilibrium for floating paraboloidal segments. (*On Floating Bodies* I and II.) These results stand on a level with those on the center of gravity—among the greatest achievements of Greece in mathematical science.

Archimedes apparently did not write on dynamics, but in the works of Aristotle there are a number of references to simple laws of motion. The most significant of these is probably the parallelogram of velocities, incorrectly ascribed to Galileo. We read:

> Now if the two displacements of a body are in any fixed proportion, the resulting displacement must necessarily be a straight line, and this line is the diagonal of the figure, made by the lines drawn in this proportion. . . . And the converse is also true. It is plain that, if a point be moved along the diagonal by two displacements, it is necessarily moved according to the proportion of the sides of the parallelogram; for otherwise it will not be moved along the diagonal. (*Mechanica* 1: 848b. Cf. 23: 854b–855a.)

This formulation does not differ in essentials from that given two thousand years later by Newton in the *Principia:*

> A body, acted on by two forces simultaneously, will describe the diagonal of a parallelogram in the same time as it would describe the sides by those forces separately.[4]

The corresponding law of the parallelogram of forces is not expressed by Aristotle, but it is easily deduced from his recognition that the force which moves a given weight is directed along the path of motion and from his oft-repeated idea that

> If, then, A the movent have moved B a distance Γ in a time Δ, then in the same time the same force A will move ½ B twice the distance Γ, and in ½ Δ it will move ½ B the whole distance Γ: for thus the rules of proportion will be observed. (*Physica* VII. 5: 249b–250a.)

There are also in the works of Aristotle anticipations of the idea, widely but erroneously ascribed to Galileo, of uniform acceleration, as well as a first approximation to the law of falling bodies:

> In rectilinear locomotion [vertically downward] the motion of things in leaving the starting-point is not uniform with their motion in approaching the finishing-point, since the velocity of a thing always increases proportionately as it removes itself farther from its position of rest. (*Physica* VIII. 9: 265b. Cf. *De caelo* I: 8.)

This is the idea to which Galileo was first led, but which he discovered to be false; the velocity is proportional to time rather than distance. But it appears from another passage that Aristotle correctly regarded acceleration (whether uniform or nonuniform) as a time rate of change of velocity:

> Perpetual acceleration [of the heavens] is impossible . . . if we may take acceleration to proceed by identical or increasing additions of speed and for an infinite time. (*De caelo* II. 6: 289a.)

Moreover, there are passages which are quite suggestive of the first and third of the so-called Newtonian laws of motion.

> Bodies which are at rest remain so owing to their resistance. (*Mechanica* 8: 851b.)
>
> When one is running fast it is difficult to divert the whole body from its impetus in one direction to some other movement. (*De audibilibus* 804b.)
>
> The force of that which initiates movement must

be made equal to the force of that which remains at rest. For there is a definite quantity of force or power by dint of which that which remains at rest does so, just as there is of force by dint of which that which initiates movement does so; and as there is a necessary proportion between opposite motions, so there is between absences of motion. . . . For as the pusher pushes so is the pushed pushed, and with equal force. (*De motu animalium* 3: 699.)

There is also a striking passage which adumbrates Huygens' law that in circular motion centrifugal force varies inversely as the radius, as well as the notion of components of velocity. One reads that when an object moves along a curve, it does so

naturally along the tangent, and unnaturally towards the centre. And the lesser radius is always moved more in respect of its unnatural motion; for being nearer to the retarding centre, it is more constrained. (*Mechanica* 1: 849a.)

Interpretation of such passages in dynamics, however, should be made cautiously in the light of the context, for Aristotle was far from modern in his idea of the relationships involving inertia, force, weight, and motion. Peripatetic dynamics concerned itself empirically with concrete cases of real motions in a resisting medium, instead of beginning, as did Galileo, Newton, and Huygens, with an abstract study of hypothetical motions in a vacuum. For this reason Aristotle naturally rejected the idea of perpetual uniform rectilinear motion which would be implied in the ideal situation by the principle of inertia, and he developed instead the doctrine that continued motion was possible only through the application of an external *vis a tergo*. In this situation velocity—rather than acceleration—was proportional to force, and varied inversely as the density of the resisting medium. (*Physica* IV. 8: 215b; VII. 5: 250a.) This assumption implies that bodies fall through a resisting medium with speeds proportional to their weights, a conclusion which Aristotle—and, later, Leonardo da Vinci—accepted (*Physica* IV. 8: 215b; *De caelo* IV. 1: 308a) but which, even for terminal velocities, is not in close agreement with experimental evidence. This discrepancy has appealed so strongly to the modern imagination that it has completely overshadowed other more valuable portions of Aristotelian quantitative science. If one points out that Aristotle was unsuccessful in his treatment of dynamics, it should also be noted that Archimedes hazarded nothing on this subject, and that Leonardo committed comparable errors in his laws of motion.[5] Even Galileo, in his early treatise *On Motion*, had at first held similar views; and in his mature and brilliant work on the *Two New Sciences* very inadequate consideration was given to the effect of a resisting medium.

The first branches of science to be given mathematical form had been astronomy and music, subjects to which Aristotle was much attracted. He sought to improve on the Eudoxan planetary scheme of homocentric spheres by giving it a greater appearance of physical reality (*Metaphysica* Λ 8: 1073b–1074a); and after having given numerous excellent reasons for believing in the sphericity of the earth, he has handed down to us in a striking passage what appears to be the first known estimate of the size of the earth:

Hence one should not be too sure of the incredibility of the view of those who conceive that there is continuity between the parts about the pillars of Hercules and the parts about India, and that in this way the ocean is one. . . . Also, those mathematicians who try to calculate the size of the earth's circumference arrive at the figure 400,000 stades [or about 40,000 miles]. This indicates not only that the earth's mass is spherical in shape, but also that as compared with the stars it is not of great size. (*De caelo* II. 14: 298a. Cf. *Meteorologica* I. 3: 339.)

In music Aristotle continued the Pythagorean interest in the numerical aspect of harmony and made contributions to acoustics in general. To the Pythagoreans has been attributed the idea that the simpler the ratio of the two parts into which a vibrating string is divided, the more perfect is the consonance of the two sounds. Aristotle saw the operation of this principle also in connection with reed-pipes.

In the reed-pipe an accord in the octave is obtained by doubling the length, and this is how flute-makers produce it. Similarly they obtain a fifth by means of a length in the ratio of 3 to 2, . . . and a fourth by means of a length in the ratio of 4 to 3. (*Problemata* XIX. 23: 919b.)

Aristotle extrapolated beyond these results and speculated that consonance is produced only in the case of lengths the ratios of which are of the form $\frac{n+1}{n}$ (*Problemata* XIX. 34: 920a and 41: 921b). This quantitative formulation is satisfactory, however, only for small integral values of n.

In connection with musical problems Aristotle recognized also the importance of frequency, noting that

> more frequent impacts upon the air are caused by the shriller note. (*De audibilibus* 804a.)

and that

> strings which are tightly stretched give a shriller note, for their movement is quicker. (*Problemata* XIX. 35: 920b. Cf. also 50: 922b–923a.)

Since he held that proportion is order, which is naturally pleasant, it followed that

> sounds in a concord stand in a proportion of movement to one another. (*Problemata* XIX. 38–39: 921a.)

The implication seems to be that the proportions here are the same as those for lengths, such as 2 to 1, or 3 to 2, or 4 to 3, an anticipation of the relationship between tone and frequency which ordinarily is ascribed to Galileo. However, Aristotle (or his students) sometimes confused frequency of vibration with speed of transmission, and held that the higher the pitch the greater was the velocity of the sound. (*Problemata* XI. 3: 899a; 14: 900a–b.) Observation alone had made it clear to him that sound takes time in transmission (*De sensu* VI. 446b), but the values of the speed under varying conditions could have been determined only by careful measurements, such as those made in the eighteenth century. In connection with the formation of echoes, however, he correctly pointed out the equality of the angles of incidence and reflection (*Problemata* XI. 23: 901b. Cf. 51: 904b), a quantitative Aristotelian contribution which has been generally overlooked. In this connection Aristotle made a further observation which apparently was neglected for some twenty-two hundred years. Rayleigh believed, in 1873, that he was the first one to notice that in echoes the upper components of a complex note predominate, with the result that an increase in pitch frequently is observed. (*Nature* 8: 1873, 319–320.) However, Aristotle had observed this alteration of pitch, saying that "the sound of an echo is distinctly shriller" (*Problemata* XI. 6: 899a. Cf. also XIX. 11: 918a), although he failed to note the relationships which led Rayleigh to refer to the phenomena of differential reflection as "harmonic echoes."

There are numerous places in Aristotelian works where one finds the germs of concepts which have since been given mathematical formulation. With respect to heat Aristotle held that

> Movement tends to create fire in wood, stone, and iron (*De caelo* II. 7: 289a);

and on the luminiferous aether we read that

> Of this substance light is the activity. (*De anima* II. 7: 418b.)

Nevertheless, such statements, anticipating the kinetic theories of heat and light, were not made quantitative and so remained unconvincing for well over two thousand years. After this time the use of precise measurement in connection with new scientific instruments supplied a wealth of numerical data which made mathematical treatment possible.

The citations given above show that Aristotelian quantitative physics, while less accurate than that of Archimedes, was of far wider scope. There is one striking characteristic, however, which the two have in common: there is in both a complete absence of the use of measurement, either as a preliminary step or in experimental verification. Both men began with careful observation unaided by the use of instruments, and upon the results of such observation they built a deductive science. Aristotle and Archimedes differ less in method than in attitude. Archimedes, the mathematician, limited himself to a small number of observations comparable in exactitude to the axioms of geometry. His work on the lever is deduced from three postulates:

> 1. Equal weights at equal distances are in equilibrium, and equal weights at unequal distances are not in equilibrium but incline towards the weight which is at the greater distance.
>
> 2. If, when weights at certain distances are in equilibrium, something be added to one of the weights, they are not in equilibrium but incline towards that weight to which the addition was made.
>
> 3. Similarly, if anything be taken away from one of the weights, they are not in equilibrium but incline towards the weight from which nothing was taken. (*On the equilibrium of planes* I, postulates 1–3.)

The elaborate propositions on center of gravity are deduced from four further simple assumptions:

> 4. When equal and similar plane figures coincide

if applied to one another, their centres of gravity similarly coincide.

5. In figures which are unequal but similar centres of gravity will be similarly situated.

6. If magnitudes at certain distances be in equilibrium, (other) magnitudes equal to them will also be in equilibrium at the same distances.

7. In any figure whose perimeter is concave in (one and) the same direction the centre of gravity must be within the figure. (*On the equilibrium of planes* I, postulates 4–7.)

The work on the hydrostatic principle and the equilibrium of floating "conoids" similarly follows from the following premises:

1. Let it be supposed that a fluid is of such a character that, its parts lying evenly and being continuous, that part which is thrust the less is driven along by that which is thrust the more; and that each of its parts is thrust by the fluid which is above it in a perpendicular direction if the fluid be sunk in anything and compressed by anything else.

2. Let it be granted that bodies which are forced upwards in a fluid are forced upwards along the perpendicular [to the surface] which passes through their centre of gravity. (*On floating bodies* I, postulates 1 and 2.)

The science of Archimedes is therefore quite comparable, in the certitude of its logical perfection, to the *Elements* of Euclid. It is applied mathematics rather than experimental physics.

Aristotle, the philosopher, likewise proceeded from observation, and for this reason he frequently is regarded as the father of induction; but he did not restrict himself to a few self-evident elements of experience from which he might deduce with mathematical precision other quantitative functional relationships. In an eager search for certainty, he surveyed the whole of nature with an eye to determining its essential oneness as to cause and purpose. He began with phenomena, but he proceeded prematurely to use deductive methods and sought to ascend to metaphysical principles. Form was consequently of more significance to Aristotle than was measure, even though he frequently passed from a purely qualitative point of view to quantitative formulations. He recognized that "our most accurate sciences [are] the mathematical" (*De caelo* III. 7: 306a), but his use of mathematics was nevertheless incidental and more for purposes of illustration than for methodical elaboration. At heart he was a teleologist, and he recognized that mathematical science takes no account of good or evil—that number is neither cause nor agent. (*Metaphysica* N. 5: 1092b.) The etiological question, "Why?" held greater attraction for him than the search for the quantitative description, "How?."

The *Physics* of Aristotle is a coherent and systematic treatment, starting from common sense; yet in its reluctance to associate concrete situations with mathematical abstractions, it bears less resemblance to the subject known today by this name than do the mechanics and hydrostatics of Archimedes. Yet in general characteristics the attitudes of these two great ancient scientists were similar: they both hoped for too much from logical demonstration based on premises established through mere unaided observation. There is missing in their works the third step of the method now so successfully exploited —the framing of an hypothesis, followed by deductive elaboration, and then completed by experimental verification (usually in terms of measurement) of the logical implications of the hypothesis. One may, in a very broad sense, recognize three stages in the development of science: speculation, observation, mensuration. The physics of Aristotle and Archimedes is representative of the second stage. As Jeans would put it,[6] these men depended upon "facts as they are revealed by our primitive senses," rather than upon those "revealed by instruments of precision." Indeed, Archimedes' recognition of two cases in connection with the lever, according as the ratio of the arms is commensurable or incommensurable, is inconsistent with the very idea of the precision of measurements. Distinctions between rational and irrational magnitudes have no significance in empirical quantitative determinations. Archimedes apparently did indeed determine densities through the use of the balance, but it is to be noted that this constituted only a technological application of his theoretical results. Such determinations were not made for the purpose of collecting preliminary data, nor were they intended as verifications of the hydrostatic principle which had been established through the certainty of mathematical proof.

In the case of Aristotle one fails to find even such technological links between science

and measurement. He classified physics along with mathematics and metaphysics as a theoretical science, and hence he stressed the syllogistic approach. Although he considered at length such ideas as magnitude, time, and weight, his arm-chair physics stands in sharp contrast to his field-work in biology. It is customary to excuse this omission of quantitative study as due to a deficiency of those instruments which played so large a role in the age of genius during the seventeenth century; but this explanation is inadequate. The ruled straight-edge, the graduated water-clock, and the scale or balance were well known in antiquity and could have been used to good advantage in physical experimentation. With these Aristotle might easily have detected his errors with respect to the speeds of falling bodies and the velocity of sound; with them Archimedes might have created a satisfactory science of dynamics or discovered (in geometrical form) the law of refraction.

It is of interest in this connection to notice that even Galileo, long afterward, failed to make effective quantitative use of the instruments of precision which he himself had invented. Galileo was in method, although not in interests, a better Aristotelian than the Peripatetics of his day. It is small wonder, in view of his praise of Aristotle and his unbounded admiration for Archimedes, that in physics Galileo should have inherited the Greek method of deduction from premises based on ordinary imprecise observation. His descriptive physical astronomy, made possible by the telescope, stands in marked contrast to the scientifically more valuable mathematical astronomy of Kepler, based on very precise measurements inherited from Tycho Brahe. In terrestrial physics he believed at first that he had found a satisfactory axiom for falling bodies in the statement that "natural motion takes place in such a fashion that the velocity varies directly with the distance traversed." This premise was the result of crude experience rather than accurate measurement. Moreover, that this premise is untenable was disclosed to Galileo by deductive logic and not by experimental evidence: it implied the false conclusion that an object would traverse part of its path with an infinite speed. Galileo, like his Greek forebears, was concerned with theoretical rather than experimental physics.

The failure of the greatest minds of Greece to appreciate the significance of patient and accurate measurement made their work of limited value. Bold adumbrations of atomic and kinetic physical theories were unconvincing in antiquity. Had Bacon and Descartes been the only prophets of modern science, the continuation of such speculations might have remained unfruitful; but the empirical and mathematical tendencies of the so-called Renaissance were tempered by an insistence on measurement. This characteristic of modern science generally is ascribed to the rising influence of technology, but it can be traced back also to intellectual sources. The fifteenth century scholar Nicholas of Cusa has been acclaimed with overgenerous enthusiasm as the herald of a new age; but in one respect, at least, such admiration is deserved. He saw that careful measurement has a value far above that of ordinary observation. So thoroughly was he imbued with this idea that he ingenuously conjectured that the Latin word *mens* was derived from *mensurando.* The emphasis on measurement gained with time and resulted in the work of such men as Kepler, Huygens, and Newton. Observation and mathematics had played an important part in the science of Aristotle and Archimedes; but while these men counted what was numerable, they did not gauge what was measurable. Modern physics arose when the Pythagorean dictum that "All is number" was supplemented by the realization, later expressed by the chemist Liebig, that "God has ordained all things by number *and measure.*"

References Cited

[1] The translation here, and elsewhere in this paper, is taken from *The Works of Aristotle,* ed. by W. D. Ross and J. A. Smith, 11 vols., Oxford, 1908–1931. The *Mechanica* and some of the other treatises of the Aristotelian corpus are probably not by Aristotle himself, but in most cases they represent his thought. Instances of doubtful authenticity and dates of probable composition will not be discussed here as they do not significantly modify the argument of this paper.

[2] The translation here, and elsewhere in this paper, is from *The Works of Archimedes,* ed. by T. L. Heath, Cambridge, 1897.

[3] *Two New Sciences* (transl. by Henry Crew and Alfonso de Salvio, New York, 1914), p. 80. Galileo gives his figure for the specific gravity of air as 1/400.

[4] See Isaac Newton, *Mathematical Principles of Natural Philosophy* (ed. by Florian Cajori, Berkeley, Cal., 1934), p. 14.

[5] See Edward MacCurdy, *The Notebooks of Leonardo da Vinci* (New York, 1941–1942), pp. 557, 573f, 592f.

[6] Sir James Jeans, *Physics and Philosophy,* (New York, 1943) p. 84.

HOW BIOLOGY CAME TO KNOX COLLEGE

By JAMES G. NEEDHAM

THIS is a bit of academic history. As a "last leaf upon the tree in the spring," I have been asked to put on record what I know about the history of biology as a subject of instruction in Knox College. Perhaps it may be of interest as an example of what went on in American colleges after the publication of Darwin's *Origin of Species*.

Before there was a Department of Biology at Knox, before the name of biology was well known in colleges generally, a man was there who taught it. His name was Albert Hurd. His title was "Professor of Chemistry and the Natural Sciences"; but that title was far from being broad enough to cover the field of his instruction; for in his time he taught most of the subjects in the college curriculum. The faculty was small, and the many courses offered sometimes had to be parcelled out among its members in complete disregard of titles. It is the common testimony of his pupils that Professor Hurd was at his best as a teacher of Latin, but he was first of all Professor of Chemistry, and he was himself the author of a small textbook on that subject.

He came to Knox as a tutor and lecturer in chemistry in 1851, when Knox was in her second decade. He came committed to the purpose of promoting Christian education by means of a college, and he joined the little devoted band that he found there, and taught effectively whatever the welfare of the institution or the exigencies of the situation demanded. And he stayed there to teach on, to the end of his life, though the brilliance of his intellectual leadership brought tempting offers of better salary and greater prestige in larger institutions.

Albert Hurd was graduated from the old line classical course at Middlebury College with the class of 1850. He was then 27 years old. The following year he was principal of Brandon Academy in Vermont, and then he came to Knox.

He began moderately with courses in chemistry and geology for men in the college, and with other courses in botany, physiology, chemistry and geology for women in the then separate Knox Seminary.

The next year (1852–3), when he first hit his stride, his offerings in the college catalog looked like this!

FOR MEN IN THE COLLEGE

Chemistry for Juniors, a year course
Botany for Juniors, Spring term
Anatomy and Physiology for Seniors, Fall term
Geology for Seniors, Fall term

FOR WOMEN IN THE SEMINARY

Botany, 1st year students, Fall term
Physiology, 1st year students, Spring term
Chemistry, 2nd year students, Fall term
Geology, 2nd year students, Spring term

Also, demonstrations in chemistry and botany, were given to Academy students.

He was young then.

The next year, 1853–4, he offered an additional fall term course in zoology for men in their senior year. The catalog for that year mentions the beginning of a geological museum, an enterprise of his own that was destined to expand and to make large demands upon him.

The catalog also records that he was then given a master's degree, and was appointed Professor of Natural Sciences.

After three years at Knox he went to Harvard University for better preparation and studied during the year 1854–5 in the Lawrence Scientific School. No record of his work appears to have been preserved at Harvard; but I remember his speaking of Jeffries Wyman as his teacher in zoology, of Eben Horsford, in chemistry, and most of all, of that great Master, Louis Agassiz, whose disciple he became and continued to be as long as he lived.

Albert Hurd was my teacher. At first he seemed cold, distant and severe, but during my last three years in college I got to know him well. I found him kind and helpful and always interesting. He demanded that students study. Some of the more timid members of his classes approached their turn in his recitations with fear and trembling. He had an uncanny discernment of a state of unpreparedness, and his questions were searching.

Some folks said in my day that the run-

away marriage of his daughter Harriet to Sam McClure had soured him. Sam (S. S. McClure, later of popular magazine fame and now for fifty years a trustee of the college) had not made a very good showing as a student at Knox. Harriet's record for scholarship was her father's pride and joy. He objected to the marriage unrelentingly. Folks respected the old man's scholastic standards, but their human sympathies were with his lovely daughter.

Professor Hurd was a tall, spare man, smooth shaven, with black hair, an aquiline nose and a healthily ruddy complexion. There was fire in his eye and sprightliness in his step. I can see him now as he entered the class room, clad in a long black coat, white starched shirt and flowing tie. His black shoes were always neatly polished. He would take his seat at the side of a little table on the floor level, and adjust his spectacles to ride properly on the top of his nose. He would open the book on his knee, and glance assuringly at the faces of the students seated before him, with a pleased expression that seemed to say "I am going to enjoy this hour with you. We will examine together a most interesting subject. Alert all!" But no such word was spoken; it was all conveyed in the serene assurance of his presence and in the glance of his eye.

He was an upright man: simple and diligent; clean-cut in his living as in his speech. In his teaching there was no monotony of procedure; the element of surprise was never lacking. I am sure that no one ever went to sleep in any of his classes. He taught all the sciences by the lecture method, as was the rule in the colleges of his day. But he was far from being content to have his pupils learn only by hearsay. He wished them to see things for themselves whenever possible. He had no laboratory. He had only a little cubicle of a room where he prepared his material for demonstration. In chemistry he performed all the experiments himself before his class, explaining reactions as he went along, and writing formulae and equations upon the blackboard.

There was then in Knox College no laboratory for students in any subject. I remember that ten members of the class of '91, wishing to get their own hands on things, petitioned the faculty for the privilege of a little laboratory work in chemistry. This required the reuse by them of Professor Hurd's scanty materials and apparatus: and though it meant more work for him, he supported our petition and it was granted. And I should not fail to add that he aided our feeble undertaking to the limit of his time and resources.

The biology of that day appeared in colleges generally as separate courses in zoology and botany, with scant indication that they had anything in common. Yet there was some very good biology taught by Professor Hurd. I am thinking especially of a short spring term course in botany in which he was my teacher. It was mainly flower analysis, field collecting and herbarium making. It would hardly pass muster now as an introductory course in botany; but it gave first-hand contact with living plants, and it invited thinking from the things observed. That course was one of the most stimulating experiences of my college life. A great teacher used spring flowers to reveal scientific method, first in analysis and then in scientific synthesis. When he said "learn the parts of a flower, and learn to recognize them under all their disguises," he was teaching the way to study the plant world, and the animal world, and the world of human beings as well.

Sometimes I would see him coming in from the woods or the prairie, carrying an old tin vasculum filled with freshly gathered flowers for the use of his morning classes. He had no personal assistant to help him with such chores. Once I heard him say, "If you want a thing well done, do it yourself."

In the classroom he would hand out the plants to be studied. He saw to it that each one of us was supplied with plenty of good specimens for individual use. Then he led us in the examination of them: showed us what to take in hand, how to select the parts for examination. He directed our attention to the characteristics of each kind of plant studied, proceeding from general characters of form, color, and fragrance to the smallest structures that could be seen with the unaided eye. Thus he would take up one by one the different plants, beginning with the

simpler ones in which the parts are most easily recognized, making rapid sketches upon the blackboard to aid our recognition of them, and writing the names in a strong hand that was as plain as print. All the while he would be noting likenesses and differences among them; and he would always help us to remember new names by giving their Greek and Latin derivation.

After leading us through this introductory exercise, he would turn us loose to make our own record of the things seen, to go out and find and study additional species of plants, and to make our own comparisons.

We had none of the equipment now considered essential. We had only pocket knives and pins for opening the flowers to disclose their parts. At most there may have been a few simple, commercial tripod lenses of the sort known as "linen testers" available for seeing the parts of the very small flowers.

Of course this was not "general botany"; but it was good botany just the same. It has lasted me all my life. Though I am not a botanist, I still go about the earth making delightful new acquaintances in the plant world by the methods that he taught me.

The course in zoology that I had with Professor Hurd was much less practical. It dealt mainly with the groupings of the larger animals. It was a course in gross anatomy with animal life left out. The textbook was Orton's *Zoology*. The materials used in illustration were specimens brought down from his museum: mainly bones, shells, and mounted whole specimens, well selected, and well used to supplement the text. Recitations were the rule. They were illuminated by his comments, tinctured with the philosophy of Agassiz rather than with that of Darwin. Comparative anatomy was then in flower. Homologies among the parts of different animals were clearly presented and lines of differentiation among them, but these things indicated a Creator's infinite resourcefulness, rather than blood-relationship among animals. Facts were fairly, even reverently, presented, as they had been by Agassiz.

We had a chance to learn something about animals by handling the museum specimens: something of their form, size, and appearance, and gained a little first-hand knowledge of their systematic relationships. Our contacts with Nature were closer than some that came later when lantern slides were substituted for museum specimens. I fear that lantern slides have sometimes been used in teaching zoology for convenience and as a substitute for brains. And movie films, with all their merit of showing action, give still more fleeting glimpses of things. They allow no time for getting zoology into the students' notebooks or even transiently into their heads.

I remember that once when I got an opossum to mount for the college museum (I was earning my way through college by means of taxidermy), Professor Hurd offered to spend an evening with two of us dissecting it, in order that he might point out to us the peculiarities of marsupialian anatomy. A pleasant evening it was: congenial and informing.

In that day a college museum was the best of aids to the teachers of the natural sciences. It housed the materials for illustrating the lectures. Knox College had a museum, a good one. Professor Hurd had built it up from nothing at all to a fine teaching collection largely by the labor of his own hands. It contained thousands of specimens of plants and animals neatly arranged and carefully identified and labeled. A partial record of its growth is to be found in some of the older catalogs of the college. That of 1853–4 makes the first mention of it as the beginning of a geological museum. The next one, 1854–5, records the purchase for it of a human skeleton. And that old skeleton (the most enduringly useful of museum properties, serving as illustrative material for many courses) may have been looked upon more or less understandingly by every student of Knox down to this day.

In my student days Professor Hurd was still doing some collecting afield, tramping through the then uncut woodlands that lay to the eastward of Galesburg among the hills; and over the then unbroken prairie sod that bordered the Burlington railway tracks in three directions from town. On every trip he brought in specimens for the museum. And he was alert to find sources of new ma-

terials. By his arrangement I was allowed to pay my tuition and other college fees in mounted specimens. Among those that I prepared for the museum were a badger, a black bear, an alligator garfish, and many birds.

Knox in that day was divided, like all Gaul, into three parts: Knox College for men, Knox Seminary for women, and Knox Academy for preparatory students of both sexes. The campus was a square area of four city blocks, surrounded by a wooden fence, with a row of hitching posts for horses out in front. The fence was made of six-inch boards strung horizontally on round posts, that were sawed off to uniform height and capped with an added board on which whittlers could sit while discussing local politics. A new county court house stood across the way. Lawyers and ministers were then the chief products of the colleges.

There were three brick buildings on the campus: "Old Main," dominating the scene as now, in the central position, and a small, square, two-story building on either side. The lawn was regularly mowed only at the front of the buildings; rearward it was kept down by the grazing of a Swedish janitor's cow, tethered to a movable stake; or in part it was worn down by baseball practice.

Professor Hurd and the sciences had moved into "Old Main" in 1857 when it was new, and his museum occupied a wide east room on the top floor, above another wide room that served for chapel exercises.

The two small older buildings (long since vanished) were twins; identical twins: East and West Bricks. Each housed a large classroom on the ground floor, and a room for one of the two rival literary societies for men on the second floor. Behind each building, extended like a tail to the southward, there was a string of half a dozen one-story rooms that had served for dormitories, but which in my day had fallen into disuse. One of these rooms, No. 2 in West Bricks, was given over to me for my use as a shop in which to work at taxidermy. Some rooms farther back were in use for storage of coal.

During the four years that I worked there at odd hours mounting birds and mammals for exhibit purposes and for collections, I learned incidentally a good deal of practical zoology. Many curious callers strayed into my shop. Few of them failed to ask "What do you stuff 'em with?" One day while working at my bench, unheeding of a visitor who had just stepped inside, I heard him say, "I used to live in this room," and I turned around for my first meeting with Sam McClure.

The string of dormitory rooms that formed the tail of East Bricks had once, in 1858, served as the gallery for a large audience on an occasion of great historical importance: the fifth of the world-famous series of Lincoln-Douglas debates on the slavery question. A platform for speakers had been erected against the east wall of Old Main. A vast audience filled the area between, and the roof of the dormitory rooms was the gallery at the rear. Colonel Clark E. Carr, author of *The Illini*, once told me that in order to get a place where he could see (he was of Zacchaean stature) he climbed on the roof of dormitory room No. 2 and joined with other students in the cheering for Lincoln.

What to do with the women? seems to have been a troublesome question at Knox, as elsewhere. It was thought that more education would improve them. How much more they could stand and how it might safely be administered was the great twofold question. The first answer to it was the establishment of a Knox Female Seminary for them, with its own course of study and its own degree of Bachelor of Letters at graduation.

Although Professor Hurd was in many respects conservative, the breaking down of the college barriers against women seems to have come by way of his courses. Perhaps it began at the outbreak of the war in 1861, for at that time the college went on a quarter system, many students went into the army, the teaching force was cut down and economies were necessary. The catalog for that year records that Professor Hurd offered botany in the third quarter in both college and seminary. The catalog does not state that he permitted men and women to meet together as one class, but the stringency of the time probably compelled it. This educational experiment, which by that time was being tried elsewhere, seemed to work neither

harm to the women nor retardation to the men, and perhaps it was continued thereafter.

The catalog for 1867 states that men and women might be admitted to Professor Hurd's classes in "senior science": zoology and geology. Botany was still a part of the separate seminary curriculum. Botany was deemed to be a charming subject, especially suited to the feminine mind.

In 1870 women were allowed to enter the men's college; but being women, it was required that they should take six years to finish the four-year course. This stupid concession to masculine conceit did not last long. When I entered Knox as a freshman in the fall of 1887, nearly all classes in the college were open to men and women alike. In chapel, however, they were seated separately to right and left of the middle aisle. And it was an innovation sufficient to be noted in the news of the day that for lack of seating capacity ten men had to be moved over to the women's side of the room.

The academy was going out: high schools were taking over. The seminary was coming in.

Professor Hurd's attitude toward women was one of genuine chivalry; he was always deferential and dealt more gently with them than with men. Yet he could be caustic when the occasion seemed to demand it. One said to me that she was "scared to death of him." He expected punctuality. I remember that one morning two women students came straying in singly after the recitation had been begun, and when a third followed more tardily, he glanced toward the door, and said softly but distinctly, "Another lame duck!" and halted the recitation until after she was seated. He merely waited in silence and let the class by its attitude administer the discipline. Nothing more was needed. There was little tardiness by either men or women in that class thereafter.

He was more polite with women. He never said "Mr." when calling on a man in recitation; he never omitted "Miss" when calling on a woman. He used family names with both: but it was "Cushing," "Stowell," "Calkins," with men: "Miss Scott," "Miss Fraser," "Miss Corbin," with women. He told the class one day with great amusement that a good woman in town had recently asked him if it is true that a woman has one more rib than a man.

When I first entered Knox College that institution was already fifty years old. Professor Hurd had been the only teacher of the physical and biological sciences for thirty-seven years. Before his time there had been a "Lecturer" in these subjects. His name was Nehemiah Losey. I am indebted to Professor A. G. Walton, the present head of the Department of Biology, for information concerning Mr. Losey that he gleaned from the Knox catalogs of the early years. Mr. Losey's teaching began in the spring term of the first year (1837) with "lectures in chemistry and natural history." In the second year he offered a course of lectures in physiology for both academy and college students, with "attendance voluntary." This offering continued in the two years following. There was then a fixed curriculum of *prescribed* studies. Perhaps there was no time for extra lecture courses. Probably the taking of them would earn no credit toward graduation.

In 1843 chemistry appears to have elbowed its way into the list of required courses: even chemistry "with laboratory"; but the laboratory part was doubtless Mr. Losey's demonstrations before the class. In 1846 physiology and geology were added. Courses in these three sciences continued to be offered by Mr. Losey until the time of his retirement in 1850.

In my student days at Knox, Doctor Newton Bateman was still president of the college. He was the "Grand Old School Man" of Illinois. As the first state superintendent of education he organized the public school system of the state. When in Springfield his office had adjoined that of Abraham Lincoln. Bateman was the man whom Lincoln introduced to strangers as "my little friend, the Big Schoolmaster of Illinois."

He was small of stature; little more than five feet in height and rather delicately featured. He stood very erect. His eyes were blue and he always wore spectacles. In my day his hair and beard were snowy white.

He was a gentleman of the old school, soft spoken, mild mannered, dignified, full of

kindness and understanding of human frailties. He was the best-loved of the many college presidents that I have known. He had left the service of the state school system to become president of Knox, and had guided the college through the long years of poverty that followed the war between the States.

He was rarely seen about the campus except when coming and going to and from his office, where he sat almost constantly engaged in college correspondence. He wrote all the letters with his own hand, and copied the more important ones in an old, cast-iron, screw-down letter-press. I do not remember that he had any office assistant at all. He also taught one course in moral philosophy for seniors.

Galesburg was still semirural. Streets were unpaved, and in a rainy season they became quagmires of black prairie mud. Professors lived in homes on ample lots and tended their own gardens. Doctor Bateman lived on a large place on the northwestern border of the town: he playfully called it his farm. He came to the campus in all weathers in a small buggy drawn by a lethargic old horse. Professors walked.

Those were the days when college oratory flourished: when intercollegiate oratorical contests were the chief events of the college year. Doctor Bateman was himself an example of the flowery writing and grandiloquent speaking of the time. His chapel talks were lectures indeed: finished discourses, that he read to us most impressively from carefully prepared manuscripts. Professor Hurd, on the other hand, would appear on the chapel platform with an outline of what he had to say written on the back of envelopes or other scraps of paper, and with only an occasional glance at his notes, he would talk to us with a directness, orderliness and clearness that were delightful and often exhilarating. Daily attendance at chapel was required of students and faculty alike. The members of the faculty sat on the wide platform. They took turns at conducting the exercises, or providing a substitute speaker. Often the chapel platform introduced us to distinguished visitors. Always there were announcements that kept us informed of coming events. We looked forward most eagerly to the days when Professor Hurd would speak.

In that day the leaven of Darwinism was working mightily in the field of religion. The two men who would occasionally venture to discuss it in chapel were President Bateman and Professor Hurd. Of the two, Dr. Bateman was the more liberal. He was both devout and unafraid. I remember his saying to us, "Evolution is but the method by which the Builder wrought. It does not explain origins."

Professor Hurd was growing old. Burdened as he was by teaching courses in many subjects, by the care of his museum, and by his citizen's share in public duties that he never shirked, he could not keep up with the ever-accelerating progress of the sciences. He fell behind. It was not that the kind of facts and principles that he taught were, or ever will be, no longer needed. Rather it was that as a result of modern research, new stores were accumulating in the house of knowledge and must needs be made accessible to a new generation of students. He pleaded with his public for enlargement of the facilities of the college for teaching the sciences. A report in the *Galesburg Republican-Register* of the Founder's Day meeting of 1893 says that he appeared as the last speaker on the program and told the alumni that Knox College was poor in the scientific branches; that without better provision in these, she would miss her opportunities. He said that for forty years he had been the only instructor in chemistry and the other sciences, and for most of that time he had been teaching Latin besides. "No longer can this be," he said, "for men must be more than instructed; they must be educated."

Change was in order. His own textbook of chemistry he knew to be outmoded. He attended a meeting of the American Chemical Society in Chicago, and on his return went into the president's office and sat down dejectedly and said: "I no longer know the subject of chemistry. I should not be assuming to teach it in college." So he felt also about the other sciences; and no one was more glad than he when later he was enabled to hand over the teaching of them to younger men. He continued to teach unchanging

Latin in his own incomparably gifted way to the end of his life.

President Bateman too had grown old in the service. He had not clung to office; the office had clung to him. Where could a suitable successor to such a man be found? He was earnestly urged to continue at the helm long after he told the trustees of the college that they should be finding a younger man for his place. He finally got them to call one of his ablest and most loyal pupils, John Huston Finley, to be his successor.

That was a happy choice. Doctor Finley came to the presidency of the college in 1893. He was then twenty-nine years old. He had graduated from Knox in 1887. He had earned his doctor's degree at The Johns Hopkins University; had served with the New York State Charities Association, and had been editor of the *Charities Review*. He knew conditions at Knox; he was a loyal son, and was ready to spend and be spent in her service. His genial personality, his scholarly attainments, and his modesty made friends for the college wherever he went.

He was a lover of the ancient classics, but he was also a lover of humanity, and he saw that the day of great happenings from the development of modern science was at hand. He sought to broaden the outlook of Knox students by bringing in distinguished scholars from other institutions to speak to them. Among those who came the first year (and again the second) there was one biologist, Edward A. Birge, professor of zoology (and later president) of the University of Wisconsin, who gave a course of six lectures on heredity.

In the spring of 1895 I had the good fortune to receive a call from Doctor Finley to come back to Knox and teach zoology and natural history in a summer session for teachers that he had just inaugurated. After my graduation in 1891 I had been for two years instructor in science in the Jerseyville Illinois High School—two good years, that brought me life-long friends. I had spent another year in postgraduate study at The Johns Hopkins University. There under the direction of that great zoologist, Doctor William K. Brooks, with whom I had several courses, I was properly put in a freshman class in general biology, conducted by Doctor E. A. Andrews. That was my first experience in a biological laboratory. I owe much to the helpful interest of Doctor Andrews. I believe that the work I had in physiology with Doctor William H. Howell was also in an undergraduate course.

With such admixture of the old and the new in biology, I came back to Knox to teach it. For the work of that first summer session I had the same special equipment that Professor Hurd had had before me—precisely none at all. But by following his example and his methods I got along. The outcome seemed to be satisfactory, for Doctor Finley had me appointed instructor in the natural sciences for the following college year.

That was the year that a course in general biology first appeared among the offerings of the college catalog. A new and modernized curriculum had been arranged—projected on the basis of needs, and in the faith that the needs would be met. I had expected to give some such course as the one I had taken under Doctor Andrews; but there was no money available for equipping a laboratory. How to modernize without money was the hardest question confronting the young president. The new curriculum had to be readjusted and that course in biology postponed for a year. For the first semester I was given, instead, *five classes in plane geometry*, and for the second, I was shifted to the academy to teach natural history after the old method.

Attendance at the college was growing, and when my second year came around a course in general biology could be postponed no longer. It was up to me to give it. The same first-floor room in the old East Bricks in which I had taught plane geometry was to serve as a laboratory with no change except the addition of a few old tables. There were but three microscopes available. One of these, a good one, belonged to Professor E. L. Larkin, who had been brought in to teach astronomy and physics. The other two were so poor that things were viewed through them "as through a glass darkly." Worse still, due to the delay the number of students who had to have the course was now 165.

Here was the severest test of all my teaching experience: what could I give my students to do in the prescribed laboratory periods? Without microscopes, protoplasm, cell constituents, cell division, mitosis, and all the basic phenomena that underlie plant and animal alike and whose discovery brought about the recognition of the science of biology, could not be seen. And demonstration of them to 165 pupils one at a time was utterly impracticable.

In the laboratory I used the book that required a minimum of microscopic work. I began with the grasshopper, and then made substitutions of my own for large parts of that book. I based new studies on materials that chanced to be locally available (a phenomenal emergence of the 17-year cicada that occurred that year being one of the extras). In so doing I learned how full the world is of illustrative materials for general biology, and how much of it can be seen without microscopes. Gathering this material kept me on the jump, but it yielded valuable experience and in thirty years of subsequent teaching, I never had a more eager or more diligent class.

At the end of that year I won a graduate fellowship at Cornell University and was given leave of absence from Knox. Doctor William E. Castle was appointed in my place.

I had, of course, been clamoring for microscopes and a real laboratory; and I never realized the difficulties President Finley had in procuring them until I received a letter from him in February 1940, a few weeks before his death. He then wrote: "You organized the Department of Biology. Will you not let me have for the archives of the college your account of the beginnings—not forgetting John Brashear,* who let us have a dozen microscopes 'on tick'?"

The first semblance of a real Department of Biology in the college, the first assistant in biology (Mr. G. B. Smith) and the first biological laboratory worthy of the name came with Doctor Castle (1896–7). The college catalog for that year states: "The Department now has twenty-one compound microscopes, one dissecting microscope, a microtome, embedding apparatus, and many microscopical preparations for study." Doctor Castle organized the laboratory: the department, like Topsy, just grew.

After one year at Knox, Doctor Castle was recalled to Harvard University for a distinguished career among the world's leaders in the study of heredity, and Doctor Herbert Vincent Neal was appointed Professor of Biology in his stead.

Doctor Neal was a distinguished zoologist. He continued to develop and strengthen the department for fifteen years. He and his capable wife, Helen Howell Neal, were both good teachers, of winning personality who rendered long and excellent service to the college and to the community.

Now I have set down in writing what I remember and in part what I think. This narrative is my fulfillment of Doctor Finley's request. Beyond the point of my own departure from the Knox faculty, there are others better qualified than I am to continue the story.

* John Brashear was an independent maker of optical instruments, and an inventor of note, who doubtless extended the credit because he knew John Finley.

SHADOW AND SUBSTANCE IN CULTURAL RELATIONS

By GEORGE C. VAILLANT

THE United States Government has been experimenting in the field of international cultural relations during the past few years. The Department of State, the Office of the Coordinator of Inter-American Affairs, the Department of Agriculture, the U. S. Public Health Service, along with several other agencies, have had a hand in the program. Although the project has been extended to China and the Near East, the main emphasis has been on the Latin American Republics. There has been much criticism in terms of specific failures, and much praise for the general policy.

No two persons define cultural relations in precisely the same way, since culture means highly intellectual pursuits to some, long-haired, panty-waisted caperings to others, and to yet another group the somewhat formidable field of all those human traits, possessions, and activities not biologically transmissible from one generation to another. Yet basically the program works toward direct understanding between peoples as opposed to their more formal contacts through their embassies, their business organizations, and those other types of collective framework, which so often obscure the human aspects of a nation's life.

As an archaeologist in Mexico, I had an opportunity to study cultural relations in ancient times, and at the same time to witness on a contemporary plane the great progress in social and intellectual understanding between Mexicans and North Americans in an era when political and economic relations were somewhat strained. I likewise had the honor of being the first Cultural Relations Attaché in Peru, a post which gave an opportunity firsthand to observe the effects of our new government policy. As a result of these two decades of active participation as an individual, a representative of an educational institution, and a governmental employee, it is my belief that international cultural relations are basic to human understanding and should be recognized both officially and unofficially.

To develop such bonds of mutual interest between one country and another without a prolonged period of previous contact is difficult. It is not like putting on an advertising campaign where producer and consumer are familiar with the same symbols of ballyhoo. The situation is much more akin to those subtle processes that build up the true reputation of a hospital or university, which must rest on solid services, not cures bordering on the craftsmanship of witchcraft nor the meaty prowess of a football team. To renounce an idealistic goal, like the promotion of cultural relations, because it is difficult to convert the results into facts and figures like those of a commercial campaign, seems almost equivalent to the official abandonment of those spiritual values by which man has been able to ameliorate and dignify the apparent hopelessness of his terrestrial lot.

Cultural relations first put in their appearance when men began to form themselves into societies and started to trade and borrow from their neighbors such ideas and techniques and things as could enrich their own lives. It seems too far removed from human experience to include, as antecedents to joint enterprises which belong more strictly to the realm of economics, such symbiotic relationships, as those between the rhinoceros and the rhinoceros bird, or the shark and the sucker fish. Nonetheless trading and borrowing between nations still continue in terms of hats, sonatas, mathematical theorems, and governmental systems, instead of in terms of pots, flint knives, and new gods, as in the past. Where economically and intellectually developed, interchange such as has existed for many years between England, France, Germany, and the United States, makes the process of maintaining and stimulating cultural relations easy and fruitful; but where such an interchange has not been fully established, a productive relationship is much more difficult to achieve.

France, through the media of its government and its nationals, cultivated cultural relations more assiduously, perhaps, than

any other European country since the downfall of the Roman Empire. The intellectual and artistic influence of France has penetrated more deeply and more widely than that of more powerful nations which exerted greater pressure in a military and economic sense. Furthermore, this development of cultural relations on the part of France enabled her to live down political activities that awakened bitter hostility on the part of her rival nations. To much of the outside world there was, and perhaps still is, a very clear distinction between the government and politics of France and the culture and collective intellect of her people. The French cultural relations program was not basically an administrative scheme although the government recognized its value. Rather, these activities represented a delicate equilibrium between the creative and the administrative aspects of the country, enriched by a willingness to receive stimulation from outside sources.

In this troubled era of the mid-twentieth century, the United States has an opportunity to represent to the world-at-large spiritual and social values which promise much hope to mankind. Yet our culture and way of life still lack many of the elements necessary fully to merit that honor. As a country we have adopted strangers by the tens of thousands and the millions, and, despite very different cultural backgrounds, we have incorporated these myriads of immigrants into our American way of life. However, we have not been so successful in instilling with a friendly and admiring attitude toward our way of life those people who do not want to become our nationals, either at home or abroad. That almost mystical France of the non-French which represents pre-eminence in music, painting, and architecture, as well as liberty, equality, and fraternity, does not have a prevailing equivalent in the United States of today, unless it could be among the restricted circle of international luxury-seekers who must now find in Florida and New York those futile privileges which once they could find in France.

Nevertheless, those who penetrate our gigantic economic frame can find among North Americans a warm way of life, high spiritual values, opportunities for individual progress, and a profound sense of humanity; yet to many men of other nations the very size of our country and its organizations is repellent. Moreover, many of our American citizens seem to grow an outer carapace of rigid technique to withstand the demands of work within our exacting economy, and this shell tends to restrict the suppleness of mind and custom essential for life in the world of others, so that in a sense the exigencies of daily life in North America restrict the sphere of our general interests.

In the United States we have developed a complex and majestic educational system embracing a wide range of training. We have thousands of schools, hundreds of universities, in terms of formal education. There are scores of well-staffed public libraries, and dozens of museums which offer, on an informal basis, the raw materials of civilization and guidance thereto. However, when our citizens are placed against a foreign background, as in Mexico or Peru, their educational opportunities seem to have produced individuals who are hard, narrow, and specialized to the exclusion of the broad aspects of human understanding.

We have made profound obeisances to the civilizations of England, France, and Germany, respecting what they had to teach us, and we have even saluted distantly the ancient world of Egypt, Greece, and Rome. Yet until the outbreak of this World War, when military needs began to usurp academic sanction, great areas of the world were either neglected or at best perfunctorily treated. Channels of communication were either nonexistent, shallow, or completely blocked between the men and women of the United States and China's four hundred millions, the millions of people who use the Spanish tongue, the countless hordes of India, the awakened masses of Russia, and the dimly conceived myriads of white, brown, and black Africans.

If the present trend of foreign relations continues along the lines to which we have morally committed ourselves for years to come, we are going to have increasingly close contact with these great populations of other continents. We are not going to be able to receive these millions as immigrants and process them into the North American sys-

tem. No one should think that the gift of a few educational moving pictures, some self-laudatory articles placed in the foreign press, and canned radio programs is going to convert the rest of the world's population into mirror images of ourselves. Strident good wishes and accurately drawn blueprints drafted within the United States cannot answer the economic and governmental problems of old, old cultures developed through the millennia and to answer specific social and regional needs. We shall have largely to work in terms of other people's rules, and the old saying "Who pays the piper calls the tune" is not applicable to those whose ears are not attuned to bagpipe music.

I am not one to yearn to be a national of another country, a member of a different social class, or a person who lives in another era. I likewise can understand an equivalent lack of desire on the part of a citizen of another nation to be Americanized. I feel that some of our propaganda in Latin America has been ingenuous, if one may be permitted to use in charity that adjective as a synonym for stupidity about the economic, social, and cultural background of others. For example, in the United States we know what we mean and therefore discount our advertising when it refers to the war effort. On the other hand, to many sensitive Latin Americans it is inconceivable that a nation fighting for its life can view with equanimity ads which show its soldiers immaculately dressed on the fighting fronts, its women taking men's places in the factories but maintaining lipstick, polished fingernails, and wearing overalls tailored to promote sentimental ardor.

Therefore I believe that a strong cultural relations program on the part of the United States must have its base within our own country, and within our frame of formal and informal education. It should embrace a clear knowledge of the economic, social and cultural inconsistencies of our own civilization, as well as extend through area-language studies into the attitudes of other nations. If we were able to envisage how some of our cultural lags, like bad writing and undeveloped painting, look to the critical eyes of other countries, and how some of our racial inequalities appear to the outside world, we could more justly defend the broad humanitarian base of most of our social and educational thinking.

If we recognize the extraordinary geographic and technical advantages with which our country has been endowed through no effort of our own, we may also take pride in the full usage we have made of these gifts. We have been able to handle, within our own geographic borders and in terms of our individual states, differences in geography, climate, economic opportunity, and cultural background with considerable tolerance and understanding. It is well within the realms of possibility that we can extend such attitudes to the world-at-large. Yet we should be clearly conscious of our many sins of omission and commission, which appear the greater because of the privileges of our own development.

Such a shift in educational emphasis cannot be achieved by administrative fiat. We have too long and too zealously defended education from government control. There are signs through the swell of interest toward studies combining language with human geography that we are developing this broader attitude through the collective thinking of our more extroverted educators. Such a transition, no matter how seductive the directive philosophy, is not made overnight, for methods of education are resistant to change. Moreover, it is a truism that teaching cannot be effective without knowledge, and knowledge is acquired only by a long, laborious process of building up the necessary reservoirs of information for those lands and peoples outside of our previous orbit of learning. It is at this point that we come directly within the scope and sphere of the cultural relations program of the United States Government and what it can accomplish.

The cultural relations program cannot operate in a vacuum. It cannot exist alone within the confines of a government bureau. It must receive encouragement and acceptance from the nongovernmental world. Basically, the problem is to expose the greatest number of North Americans to society and thought in other countries and to achieve reciprocal attention from other nationals in terms of the United States. The reduction

of endowment income and slackening of the rate of endowment accretion on the part of foundations and institutions of learning make it difficult in the extreme for that broadening to be carried on entirely by private sources. Yet the preparation of personnel, both in terms of social attitudes and technical knowledge, of necessity must rest with private agencies, be they educational or economic. Our Government can take and is taking steps to facilitate the process of international understanding through the medium of technical missions, travel grants, cultural institutes, and by adding to the personnel of embassy staffs individuals whose duty it is to watch and cultivate cultural relations.

THE technical missions sent from the United States to the republics of Latin America, to China, and to the Near East, with the possibility of further expansion in the future, have very definite advantages, judging from results in the fields of public health, agriculture, and vocational education. The disadvantages of the mission idea are perhaps psychological, rather than practical. The larger a mission the more unilateral it becomes. A friend of mine compared a large eleemosynary enterprise of this type to a kind of spiritual diving bell: the members of the organization were so completely sealed in by United States administrative methods that they did not function in terms of the social elements of the nation which they were serving. Local employees who were taken on, entered into a minor North American world, but there was little or no give-and-take with the national population in general. Such an organization set up to stimulate and teach something we take for granted, like child guidance, may well return after its tour of duty leaving nothing behind to continue. The social, economic, and governmental backgrounds may be so foreign that its function cannot be fruitfully grafted into the social structure of the nation. In such cases an organization, while performing valuable and essential tasks in reaching and developing social and economic life and thought of the United States, may be nothing but a nonfunctional luxury in a country which cannot afford its maintenance or is not yet ready to accept its social implications. This situation comes into the category of putting a modern American bathroom with all its fittings into a house in a town which has no water supply, an infelicitous example of which I once had occasion to observe.

The travel grants and aids to scholarship seem, in the long run, to be very much more effective means of promoting cultural relations since individual nationals have an opportunity to find their own spiritual and social circles. The individual has opportunity to meet people with kindred interests and to penetrate into the life of a country, as it is lived, as opposed to how it is administrated.

There are few adverse reports from Latin American students who returned from study in the United States. In a certain number of cases, the criticism which such students have to offer is that it is difficult to reconcile the individual values of friends whom they have made in the United States with the collective attitudes and actions of the American colony resident in their own nation. I know myself that the experience of individual North American students and research men in Latin America has been infinitely more happy and productive of richer friendship and understanding than that of most North Americans who have gone to Latin America as members of some governmental or business organization.

The accumulation of rich individual experience will lead in the long run to much deeper understanding than the process of trying to interarticulate bureaucracies and governmental agencies of one country with those of another. Such a process as that of individual exchange must be slow. Its full effect probably cannot be seen for another generation, but it is worth the trouble. Individual writers and students, like William Hickling Prescott, Charles Ticknor, Charles Flandrau, Stuart Chase, Thornton Wilder, and William L. Schurz, have done more for inter-American relations than many of our ambassadors. Reciprocally, Diego Rivera, Orozco, Carlos Chavez, and Ezekiel Padilla, a writer as much as a statesman, have enormously enhanced the relations between Mexico and the United States. The creative and productive individual is at the heart of international cultural relations.

Cultural institutes set up in various Latin American cities to facilitate knowledge of North American life and language offer good possibilities in international understanding, if they are skillfully and intelligently directed. Their most effective function is that of an agency for public benefice, like libraries, museums, and equivalent institutions within the United States. Their development will be slow. It will be necessary to create a clientele. Yet they offer a means of contact between the economically and intellectually unprivileged in the larger cities and various aspects of North American life. Good and inexpensive language teaching is the basic function of most of these institutes, but lectures, moving pictures, exhibitions, and maintenance of good libraries are valuable supplements to their work.

It has become readily apparent that an institute should not be a direct propaganda agency. Yet one of the great dangers which the institutes run is that they may be forced to do propaganda according to the methodology of high-pressure North American advertising in order to sell the United States to Latin America, a task which is building on sand. Salesmanship implies a competition between products, a lauding of the good points of an article, and the suppression of its defects. The same spirit of tolerance and self-criticism, which is so much a part of our life in America, should be made evident in our institutes. The range of choice of interest or of point of view likewise should be evident in these organizations. The institutes should be easily accessible storehouses where each individual may take what he wants of the American way.

The selection of personnel to run the institutes and to teach requires the most judicious treatment. To run an institute requires all the gifts necessary to manage a public service agency within the United States; in fact, even greater since the institutes must operate in a foreign atmosphere. There has been in the past, but this is being corrected now, a tendency to undervalue the skill and feel for human relationships necessary for the personnel of such organizations. Ideally, an institute should be able to furnish that which the local community collectively and individually desires to absorb from us or to know about us, just as a public library or a museum within the United States delicately adjusts its policies to the range of interest within the community it services.

There is a great sphere for Cultural Attachés since they maintain the channels between our own Embassy or Legation and the intellectual life of the country where they are stationed. Intellectual opinion may not have any direct political effect, but it may be a guide and a gauge to things to come. It also furnishes a means of appraisal of the social and intellectual significance of a country as opposed to its political strength. In many countries, in which we may include our own, there is quite a distinction between the values of governmental personnel and those of private individuals. The word "politician" or "bureaucrat" has very much the same significance in every country in the world, and yet for international relations to be carried on solely between government employees and politicians is surely much at variance with the true course of human understanding.

It was the experience of my wife and myself in Lima that the Cultural Attaché could give himself to his task better if he had held some sort of position in his own country as a humanist, scientist, or creative artist. His position rests every bit as much, if not more, on that status than on his status according to protocol. Yet, having a rank in protocol as an attaché makes it possible to meet people more freely and with less preliminary social maneuvering than would be needed by a private individual. It was our belief that it would be impossible to make a life career out of being a Cultural Attaché, that without creative production and all which the term implies, one's relations and duties would soon fall into the most superficial of activities, a cross between a contact man and a hostess in a restaurant. Moreover, in shifting from country to country one's activities would become stereotyped and there would not be the same intensity of interest that is the case when one gives oneself fully for a short period of time.

We believe that if the post of Cultural Attaché is to be maintained, it should be extended to all the countries of the world, and that the incumbents should be men and

women of distinction in many different fields so that there would eventually, in a period of years, evolve an intimate relationship between members of various professions in the United States and their confreres in other parts of the world. A man who is not a doctor, for example, cannot estimate the abilities of individual members of the medical profession. So often the men doing the most valuable work are not those who have the greatest public name, and yet it is acquaintanceship and understanding and mutual participation that have enabled the professions to be truly international, in function and in ideal. In time one could conceive of a collective body of evidence accumulating in the Embassies which would enable a hard-pressed foreign service staff to exercise discriminating guidance to visitors and background appraisal of individuals in the political scene, which would vastly enhance their work.

We have seen in Latin America hundreds of Americans coming south on government missions. Their idealism is high, their task is noble, but they move through social attitudes and traditions of the people whom they wish to help with the delicacy of a regiment of tanks. They may reach certain objectives, but behind them they leave devastation in the way of injured feelings. On the other hand, one can see a single individual, with no funds at his disposal and with no power, being able simply through the exercise of understanding and interest to build a lasting bridge between his people and his friends in the local population. He becomes a surrogate for his own nationals.

The professional foreign service personnel, ambassadors, ministers, and secretaries, have so many obligations which their métier entails that they do not, cannot, have the time for establishing close contacts in the broad cultural fields. Under certain conditions, the rules of the service would tend to prevent their associations with distinguished individuals who were politically abhorrent to the government with which official relations were maintained. In many cases, the cultural relations attachés can relieve the professional foreign service officers of many of those time-consuming, semiofficial tasks which harass our missions abroad. The reaction in Peru was most favorable to the thought that the United States through its Embassy sent a man to maintain relationship between their intellectual life and ours, irrespective of political considerations.

The nations of the world undoubtedly will be in much closer contact in the future. They will have to work in greater intimacy. Isolation will be well-nigh impossible. There will be frictions, misunderstandings, and hatreds engendered by straight proximity of contact. One will see conflict between one government and another, the agency of one government and the equivalent organization in another. One will see misunderstanding between commercial enterprises and their obligations to the social and economic interests of their own and other lands. It becomes essential that there be some sort of contact and representation between the people of the different countries, as opposed to the different organizations, and that ideal is best achieved through these various cultural relations enterprises.

In some cases where relations are established, individual communication through reading, travel, and art appreciation will do the work with relatively little government stimulus or pushing, but there are many lands in which our businesses and our government have stakes concerning which our people know nothing and whose populations cannot conceive of Americans as private citizens having a national life. In such cases, the panoply of governmental cultural relations will have to stimulate such interest through student exchange, travel grants, cultural institutes, and hard-working attachés.

The program, the procedures, the personnel are all new in cultural relations. It is experimental, but the work each year is better handled than the year before. The program has resulted in very real accomplishments. The present cultural activities, properly backed by our people and our private agencies in the United States, may do much for international relations of the future since it gives mankind a chance to know itself, with a minimum of adminstrative formality.

THOREAU'S SCIENCE

By RAYMOND ADAMS

WHEN Henry Thoreau went to live at Walden Pond exactly a century ago, no one thought of him as a scientist even as the word was used then. He didn't think of himself as a scientist. Indeed, ever since his graduation from Harvard in 1837 he had thought of himself as a teacher looking for a school, and as an author looking for a reading public, and as a land surveyor earning money by applying what he had learned from mathematics in college. He was something of a carpenter, having helped his father build a home for the family a year before and now building his own house near Walden Pond, not to mention certain fences and sheds he had built at Emerson's while he lived there in 1841. He was a gardener, though competing with the Irishmen in that occupation hardly seemed the thing for a Harvard graduate. And he was, of course, a pencil-maker, for that was the source of the family income. He had been a poet and still felt the urge to cast his ideas into arresting transcendental verses sometimes. But these were not scientific pursuits.

Thoreau had, to be sure, something of a reputation as a naturalist. But that needs qualification. Before 1845 he was a romantic naturalist surely, enjoying sentimentally the impact of nature upon him and writing so delightfully about his encounters that "poet-naturalist" (the name his intimate friend Ellery Channing gave him) is the best name for him during his first eight or ten years out of college. Lately, in *American Naturists* (1930) Henry Chester Tracy has coined the word *naturist*, "an ardent lover and observer of the life out-of-doors, wholly and somewhat naively responsive to its lures, unhappy if long deprived of its contacts." Tracy uses the word to distinguish such lovers and observers from naturalists who are scientists in the ordinary sense of the term. But Tracy's word has not fixed itself in the language. "Romantic naturalist" will have to serve for describing Henry Thoreau during the pre-Walden years.

Strictly speaking, there are no pre-Walden years in Thoreau's interest in nature. He had always known Walden. While he was a boy the family, under the leadership of nature-loving Mrs. Thoreau and exceptionally among New England families, had spent a great deal of time on nature expeditions. Walden Pond and its steep shores had been an early resort of the family and then of the boy by himself. By 1845 Thoreau had observed birds in the groves of academe adjacent to Harvard Yard, had walked to Wachusett and written an essay about the expedition, had made the great odyssey with his brother down the Concord River and up the Merrimack, had taken many a winter walk and knew much of night and moonlight. But perhaps he knew Walden best of all and surely went there no stranger when he decided to become a resident of that neighborhood. All this proves an early and abiding interest in nature, witnessed by the appearance of nature directly or in allusion on nearly every page Thoreau wrote for the magazines before 1845 and equally on every page of the remarkable book, *A Week on the Concord and Merrimack Rivers*, which he wrote while he lived at the pond, for *Walden*, a record of his life there, was written later. But, to repeat, this long interest in nature was not quite scientific. True to romanticism, he found "thoughts that do often lie too deep for tears" in the flowers he saw and could address a rhodora as endearingly as ever Emerson did. Before he went to Walden to live, he had for many years observed nature affectionately, absorbed nature as experience rather than as experiment, and known nature personally. But the approach to nature as a person is obviously not scientific; it is poetic, which is not to disparage that approach at all. There is a large place in our literature for a Thoreau, a W. H. Hudson, or a Richard Jeffries. The recording by such men charms our hearts as much as nature herself had charmed their own hearts. But theirs are

understanding hearts that sublimate their observations into emotional or even spiritual moments. If the observations are scientific, they are only incidentally so. Primarily such men are artists using the materials of nature.

Before 1845 and the going to live at Walden Thoreau had published seven prose essays, twice that many poems, and some translations or selections from ancient literature, and a few prose fragments here and there in magazines of the day. Of the seven prose essays, three might possibly have scientific content and are clearly natural history essays: "Natural History of Massachusetts," "A Winter Walk," and "A Walk to Wachusett." And these three pretty well prove the point of the last paragraph, that Thoreau before he went to Walden Pond was more romanticist than scientist. The two essays that describe walks, one westward to Wachusett Mountain and the other a circuit of winter landscapes in Concord, have little or no scientific content. They are descriptions of two walking trips, a bit stiff in composition here and there, and more concerned with the actions and reactions of the walkers than anything else. "A Winter Walk" is the better essay and contains romantic passages like this tribute to the winter sun:

> What fire could ever equal the sunshine of a winter's day, when the meadow mice come out by the wall-sides, and the chickadee lisps in the defiles of the wood? The warmth comes directly from the sun, and is not radiated from the earth, as in summer; and when we feel his beams on our backs as we are treading some snowy dell, we are grateful as for a special kindness, and bless the sun which has followed us into that by-place. (*Writings*, "Walden Edition," 1906, V, 168).

Such passages and such essays are of the stuff of romanticism, and not even Thoreau claimed they were scientific. He did better in the romantic line a few years later in essays like "Autumnal Tints" and "Walking." And one needs but compare the sentence about the blessing of sunshine upon one's back with the sunshine in the exquisite final three paragraphs of "Walking" to see how far Thoreau would go as a romantic naturalist, to say nothing of how far he would also go as a scientist.

"Natural History of Massachusetts" has more to be said for it, both as an essay and as science. It is a curiously wrought essay, beginning as a review of four natural history surveys recently published by the Commissioners on the Zoological and Botanical Survey of the State [Massachusetts], but having woven into it a great many passages from Thoreau's journal, of rather a better quality than the romantic passages in the two pedestrian essays of 1843. Perhaps because of its broader canvas, perhaps because it deals with general surveys rather than with one particular excursion, perhaps because it is more personal while being less specific, this essay is better literature than the two which describe walks. Thoreau's ideas seem more intimate because he is not confined to events so much. Yet this more considerable essay, based on four books of science, is not the work of a scientist. Naturally, Thoreau does not go beyond the classificationists in his estimates of these reports, for the reports are classifications, and biology in America about 1840 was Linneaean in its adherence to classification. Near the end of the essay Thoreau writes his definition of a man of science, and the definition proves in its emphasis on greater sensitivity and sympathy almost a paraphrase of Wordsworth's definition of a poet:

> The true man of science will know nature better by his finer organization; he will smell, taste, see, hear, feel, better than other men. His will be a deeper and finer experience. We do not learn by inference and deduction and the application of mathematics to philosophy, but by direct intercourse and sympathy. (*Writings*, V, 131.)

This is a good definition of a romantic naturalist, not a man of science. And Thoreau, whose own science for many years did not get beyond measurements and classifying and collecting, objects that these volumes "deal much in measurements and minute descriptions." We can understand what he meant. He went beyond measurements and minute descriptions—but as a romantic essayist rather than as a scientist. There is at least one passage which redeems the whole essay scientifically, the two pages devoted to the muskrat. Here, it seems to me, we get a foretaste of Thoreau's science at its best—here is the muskrat in his environment, living

through his year, the natural history of the muskrat. And the whole is objective, based on observation, accurate, detailed, and related to the entire economy of nature as Thoreau himself had observed it.

With such meager science, unhelped by his studies at Harvard from 1833 to 1837, an indifferent observer (missing especially many common birds), without binoculars or spyglass (he bought a spyglass as late as 1854, near the end of his life, and never owned binoculars), with surprisingly crude tools, and satisfied with the current vogue for classification and listing, Thoreau went to live at Walden an indifferent man of science, though a good poet-naturalist. Bradford Torrey, himself a good ornithologist, pointed out these shortcomings in his introduction to the fourteen volumes of Thoreau's journal (1906); and Henry Seidel Canby discussed it on pages 322 to 336 of his biography *Thoreau* (1939). Thoreau took up his abode in the little house beside the pond for several reasons, to straighten out his own thinking after two fearful losses (the death of his beloved brother and the failure to win Ellen Sewall), to write a book in tribute to his brother and in furtherance of his ambitions toward authorship, to test an economic theory, and to find a philosophy of life. We begin now to see scientific method emerging. His testing of his economic theory, regardless of what we may think of the theory, was a scientific testing, an experiment. His driving life into a corner and examining it was an application of the scientific method also, for he isolated his material first and then tested it. The material happened to be his own life; but the method was more scientific than his method had usually been.

The ultimate product of his Walden experience, the book called *Walden*, contains one other scientific quality. Thoreau spent much of his time at the pond measuring, observing, recording, checking, and fitting into its environment and into the seasons the lake itself. So the book is an excellent bit of limnology. How good it is can be learned from the article "Re-examination of Thoreau's *Walden*" by E. S. Deevey, Jr., in *The Quarterly Review of Biology* for March 1942 (XVII, 1–11). Thoreau himself seems to have realized that the limnology of the book was significant, for he made a careful map and included it as the only plate in *Walden*. The map contributes almost nothing to an understanding of *Walden* as a work of art nor to appreciation of the nature lore presented so attractively in the text. One can think of half a dozen other maps that Thoreau could have drawn more helpfully. But for supplementary use with a scientific account of the lake the map is very valuable indeed, giving directions, soundings, profile cross sections, sand bars, area, and such items of data. Here is indeed the geography that Canby sees running through all Thoreau's aspirations as a scientist, the "study of man's environment with reference to its effects upon man." But the limnology of *Walden* leaves man out; for once, and almost for the first time, Thoreau leaves romantic concerns behind and deals with nature objectively.

One must remind himself that objectivity is not Thoreau's forte, that science is not his aim. He did not claim to be a scientist,

> I felt that it would be to make myself the laughingstock of the scientific community to describe or attempt to describe to them that branch of science which specially interests me. . . . The fact is I am a mystic, a transcendentalist, and a natural philosopher to boot. (*Writings*, XI, 4.)

His interest in nature, landscape, darkness, or season is almost always the romantic interest of enjoying their effects upon him. Through all his writing runs a preoccupation with sounds, not the recording of bird calls or the booming of ice (though these recordings are frequent enough, too) but the charm of sounds that waft themselves to him from a distance, a drum in the night, a cow bell from some farm pasture, or a fire alarm heard at Walden from Concord village. He is a poet of sounds; they come to him sifted by distance and freed of mundane quality; they charm him even when they themselves are ordinary or harsh; they, more than anything else in his experience, are likely to start his imagination down some winsome track. The buzzed trail of a mosquito through his airy house at Walden starts Homeric thoughts in Thoreau. This use of sounds in what he wrote proves him the poet-naturalist

more than the scientist. But now and then he is the scientist.

At last, near the end of his life, in his last public lecture and the piece last published before his death, Thoreau could say in introduction, "I need offer no apology if I invite your attention, for the few moments that are allotted me, to a purely scientific subject." The subject is contained in his title, "The Succession of Forest Trees," an address read to the Middlesex Agricultural Society in Concord, September 20, 1860, and printed twice before the year was out. Indeed, he needed not apologize. This is excellent science. Put beside the early essays "A Winter Walk" or "A Walk to Wachusett" or even beside the essay-review "Natural History of Massachusetts" this essay shows a decisiveness, a confident use of reliable data, a careful assembling and checking of facts that the nature essays of the 1840's lack. Put beside the nearer essays which Thoreau gleaned from the same later journals and wrought into essays but a year later than this one, "Walking," "Autumnal Tints," and "Wild Apples," this essay on secondary succession shows scientific competence that the others lack, probably because in the others he was not speaking as a scientist but was at his best again as a romantic naturalist. Thoreau takes up a problem (Why, when a pine wood was cut down, a growth of oak sprung up, and *vice versa*) that had not been clearly explained by anyone; and, relying entirely upon his own observations, leaving nothing to hearsay, he shows why the succession is as it is, why it must always be so whenever all the conditions are present, and why the vulgar explanations are unscientific and in error. He advanced a theory and then went "to a small but very dense and handsome white pine grove, about fifteen rods square" in the east part of Concord. He carried both his theory and a measure of skepticism with him. But he must conclude, "I confess I was surprised to find my theory so perfectly proved in this case." But he knew it was in this case only. He did not stop there. He proved his theory in case after case until he had a water-tight case indeed. The essay is beautifully written; it is good literature as well as good science. And on both scores it has been neglected among Thoreau's writings. But there it is, the scientist in action.

Before Thoreau had finished his essay on forest trees, he had both proved his theory and woven into the fabric of his proof the whole environment of the trees, not excepting man. This is not quite geography, though he does not neglect geography in his essay. This is a study of the interrelations of all the elements of a given environment upon one another. I think now we can find a word to describe Thoreau in this final performance as a scientist. When he assembled his data and presented his report on the succession of forest trees in Concord he was an ecologist.

THE FOREST AND THE SEA

By MARSTON BATES

THIS title sounds like a transliteration from that of the charming book by H. M. Tomlinson, *The Sea and the Jungle*, but the similarity is what the biologist would call convergent. Tomlinson arrived at his title by travel over the sea and through the jungle, while the analogy developed in the present article is the result of reading about the sea while living in the forest. The idea of direct comparison between the biological environments of the sea and the tropical forest first occurred to me one day when I was showing one of our study areas in the foothill forest of the Eastern Andes to a botanical friend. We had lunch beside a little stream in a ravine where the forest was dark and quiet, singularly lifeless. Later I persuaded the botanist to climb the ladders on one of our trees, a dizzying experience that many of our visitors forego. We rested at the 14-meter platform, and then climbed on to the 24-meter platform, which is well up in the canopy of the forest at that particular point. It was a sunny day, and the contrast between the forest floor and the forest canopy was striking. A near-by tree was in flower and humming with insect life; mosquitoes, which had been absent on the forest floor, began to annoy us; but we had a good vantage point for bird watching and there were several birds about, including a large hawk perched on a near-by branch, apparently completely indifferent to our presence.

We had built these ladders and platforms to study the vertical distribution of organisms, particularly mosquitoes, in the forest, and we had found that each species of mosquito showed a characteristic vertical orientation, some flying only near ground, others only high in the trees, and so forth. But I had not thought about the curious parallels between the stratification of life in the sea and the stratification in the forest until this sunny day, as we sat in the treetop dangling our feet over the forest depths. We were in the pelagic zone of the forest, in the zone of active photosynthesis on which the whole complicated biological structure of the forest depended. Below we had been in the benthos, where organisms depended primarily on the detritus that drifted down from above—on fallen leaves, on fallen fruits, on roots and on the few plants that were adapted to growth in the relatively dim light of the lower forest strata.

The differences between the forest and the sea are, of course, so profound as to reduce any analogies to the level of verbal play. In the single question of stratification, the difference in scale in the two environments is tremendous. A recent study of plankton distribution that I have been reading about involves a scale of depths of 200 meters, while our mosquito distribution studies are made in a vertical band of 25 meters. To compare the "gloomy depths of the sea" with the "gloomy depths of the forest" is really so far-fetched as to be ludicrous, even though each phrase may be apt enough in its own context. Yet the basic analogy, when it is developed, shows many curious parallels that seem, at least, amusing. The real basis of similarity is that both the forest and the sea are fundamentally three-dimensional habitats. This fact has long been realized by marine ecologists, but the three-dimensional aspect of the forest has not received, it seems to me, the attention it deserves, though this is perhaps merely a single aspect of the general neglect of the biological problems of the tropical forest. Perhaps it should be explicitly noted that I am referring to *tropical* forests (and *tropical* seas); northern forests, with their characteristic uniform stands of trees and less diversified fauna do not fit the analogy so well.

The *biological similarities* between the forest and the sea stem from two conditions that these environments have in common: the vertical gradation in light, due in the one case to the arrangement of vegetation and in the other to the opacity of water; and the relative stability of the physical environment, due in the one case to the insulating

effect of a mass of vegetation and in the other to the density and thermal conservatism of water. The physical properties of water underlie the insulation and stratification in both cases—but it is water in very different conditions. The two environments are curiously different from the human point of view: we navigate on the surface of the sea, and send down instruments to study conditions at different depths. In the forest, despite our ancestry, we are a bottom animal, and we have no practical way to work at the surface (though this may be possible in the modern world with a helicopter!). Even climbing into the intermediate zones is an awkward and sometimes frightening process. For the human observer climbing is certainly more practicable than diving, but for the collection of faunal samples it is probably easier to send apparatus down, as in the sea, than to send it up, as is necessary in the forest.

The physical environment in the floor zone of the tropical forest is extraordinarily constant. We have a meteorological station at our laboratory in Eastern Colombia, in open country near the town; there the daily shade temperature usually varies between 20° and 30° to 34° C., giving a daily range of between 10° and 14°. One meter above the forest floor in our chief study area, a few kilometers away, the thermograph record looks as though it had been made in a constant-temperature apparatus. The daily range is usually 1° to 2° C. from a mean of 22°, and the maximum temperature fluctuation from one time of year to another is less than 4° C. The humidity is similarly constant in the lower levels of the forest, rarely dropping below 80 per cent relative humidity, even at midday in dry weather. Air currents within the forest floor zone are very slight. One notices this in the course of photography, for it is usually necessary to give 5- to 10-second exposures, yet there is rarely trouble because of foliage movements. Constancy of the physical environment is always adduced as one of the prime characteristics of marine habitats, and in that respect the forest and the sea are remarkably similar.

The daily fluctuations in these physical factors are least at the forest floor and become greater as one ascends into the canopy above until the extreme of fluctuation is reached in the open air at the top. Hence the vertical gradients in temperature, humidity, and light are measurable at any time in forest climate. At midday, the temperature is lowest at the forest floor, the humidity highest, and the changes as one ascends into the canopy are quite regular. The gradient in light is more irregular, depending directly on the local distribution of foliage, but it is probably preponderant in determining the zonal distribution of diurnal animals. At night the temperature gradient is reversed, the forest floor zone being warmest. Humidities at night are near saturation at all levels in the forest, and consequently this gradient is purely a diurnal phenomenon.

The gradients in light, temperature, and air movement find neat counterparts in the sea, though the scale is of course different. The great reduction of wind effect in the lower forest might be compared to the vertical limits of wave action in the sea; both permit the development of fragile organic forms that would not be able to survive in more exposed locations. But local currents and water drift, so important in the life of the sea, have no forest counterparts.

Stratification of life in the sea is possible because of the constant density of water, which allows the ready development of planktonic and free-swimming habits with consequent orientation in the vertical plane. Flight with terrestrial animals is only partially comparable to swimming, for it requires such a large expenditure of energy that it can rarely be sustained for the purpose of continuous environmental orientation. The only exceptions appear to be the forest butterflies (*Morpho heliconius*) which, freed from the necessity of combating air currents, have developed a slow, soaring flight that seems often to serve for fairly sustained orientation. In general, stratification of life in the forest is dependent not so much on the development of flight as on that of climbing ability or other adaptations to orientation with relation to the forest skeleton. Trees, forming a network of trunks, branches, twigs, and leaves, play the

role in the forest that corresponds to the density of water in the marine environment. And the swimming adaptations of marine organisms perhaps find their closest parallel in the forest in a series of modifications of structure and habit that are commonly and appropriately called "adaptations to arboreal existence."

The most obvious *biological characteristic* of a tropical forest is the diversity of kinds of its animals and plants; the forest is "rich in species." This characteristic has been described by every naturalist who has written about the Tropics. The diversity consists not merely of numerous species, but of several types—families, orders, classes. The skeleton of the forest is composed of trees that belong to a bewildering array of plant families, from palms to composites, and this same taxonomic diversity is found in the parasites, epiphytes, vines, and undergrowth that grow in it. This great mass of plant material, basic to the biological and physical structure of the forest, has no neat counterpart in the sea, and attempts at finding analogies are far-fetched.

The diversity of species and types in animals is equally striking. If we look through a list of the orders and families of American terrestrial animals, we find that the great majority have representatives in the tropical forest, and that many families and orders are largely confined to that environment. This diversity is in a real sense comparable with the diversity of the fauna of the sea, since in both cases it is related to the favorableness of the environment for life processes and to the variety of environmental niches available within the general habitat. The marine and the forest faunas are not, of course, parallel, because of their very different histories: the invertebrate fauna of the sea is composed of a host of types (echinoderms, mollusca, coelenterates, and so forth) with few or no forest representatives; while the insects, dominant in the forest, have conspicuously failed to invade the sea.

An obvious list of some of the characteristics of the tropical forest environment that make it so favorable for life includes uniformity of physical environment (climate); abundance of moisture (rainfall usually considerably in excess of 2,500 millimeters annually, fairly evenly distributed); high humidity and consequent low evaporation rate; abundance of light (in the upper canopy) and even distribution of light through the annual cycle; protection offered by the structure of the forest skeleton, and the stratification and support offered by it. Another important characteristic of the tropical forest is its vastness. One could enter the forest near our laboratory, in eastern Colombia, and go for thousands of kilometers without leaving it except to cross rivers and streams. The central body of the upper Amazon forest spreads out in bays and estuaries towards the west and the north, connecting through gallery forests with the Orinoco system, and has great outlying disconnected seas in the valleys of the Andes, and along the Caribbean coast of Central America and the Atlantic coast of Brazil. The sense of this vastness is brought home to one who flies for hour after hour over the unbroken wilderness. It was even more vivid to the old explorers who spent weeks and months painfully traversing its rivers. The metaphor "a sea of forest" has a very real meaning to the traveler through these jungles.

The parallels between this list of favorable forest characteristics and those that are usually adduced to explain the favorableness of the marine environments are striking. Uniformity of the physical environment exists in both forests and the sea. In abundance of moisture and high humidity the forest is merely approximating the ideal conditions of the sea where problems of moisture retention are not of concern to the animal world. The abundance and annual uniformity of light is of course a general tropical characteristic of seas, forests, and deserts. Where other conditions are particularly favorable, however, as in the forest and the sea, the light factor permits a vegetable accumulation that is large enough to support the corresponding diversity of animals. The protection of the forest skeleton has no counterpart in the open sea, but it is in many ways analogous to the protection to animal life afforded by the great coral reefs. The stratification of organisms in the forest and the

sea has many amusing parallels: each species of insects and of epiphytic plants apparently has its preferred level, as do different plankton species in the sea. We have even been able to demonstrate a diurnal shift in the preferred level of certain mosquito species, much like the well-known diurnal shifts in level of planktonic organisms. The vastness of the forest is, of course, dwarfed by the vastness of the sea, but the South American forest might well be compared with specific tropical seas, such as the Caribbean.

There seems to be a concentration of life at the margin of the forest that is comparable with the rich fauna of the littoral zones of the sea. This concentration is perhaps more apparent than real because the life in the canopy, normally so inaccessible, reaches the ground at the forest margin and can thus be collected and studied. It is likely, though, that the dense shrubby growth of the forest margin provides a special habitat that is particularly favorable to many species of plants and animals, and a certain number of animals undoubtedly lead a sort of amphibious existence at this forest margin, retreating into it for protection by day and sallying forth into the grassland and scrub at night.

It is interesting that much of our thinking about evolutionary problems has been conditioned by the observations of travelers in the Tropics, as is illustrated by the influence of the tropical experiences of Darwin, Wallace, and H. W. Bates. The concept of "struggle for existence," for instance, was originally tied up with the jungle law of tooth and claw. The phenomenon of mimicry was described by Bates and Müller on the basis of observations in the tropical forest, and no one who has worked in such areas doubts the reality of the phenomenon, however much observers may differ in interpretation; and mimicry is regarded as one of the great bulwarks of the theory of natural selection. The whole appearance of the forest seems to indicate a keen struggle for light, for food, for protection from enemies. The multiplicity of species, of adaptations, and of environmental niches, all unite to produce this impression. In the temperate zone one may feel at times that the main struggle of living organisms is with the physical environment—with extremes of temperature, with storms, and with sudden or adverse shifts in climate. But in the stable and benign climate of the tropical forest, the struggle seems to be more clearly among the various organisms themselves. We might well get the same impressions from the observation of life in the tropical seas except that our view of the sea is that of a foreigner floating about on its surface or awkwardly struggling down into it with diving apparatus. We can more easily become a part of the life of the forest, and many varieties of man are still completely forest animals even though their range of activities is pretty well confined to its floor zone.

There is another aspect to this struggle for existence in the tropical forest that has not been so much emphasized. The human dwellers there are all of "primitive" types that, in any measurable form of progress, have been outstripped by their fellow men of the plains. Similarly, among the host of animal species that seem to be getting along well in the struggle for existence in the forest we find *Peripatus,* archaic insects, marsupials, edentates—if you want to find "living fossils" among terrestrial animals, a good place to look for them is in the tropical forest. Here also there seems to be an analogy with the sea, where we find a profusion of very ancient types of animals living in communities that include examples of extreme specializations, and in which the struggle for existence seems to be very keen.

Of course, the populations of the South American forests are undoubtedly in part refugee populations on this peripheral continent, and perhaps the forest adaptations are a result of the fact that in South America there are few places for them to live except in the forest. My botanical friends tell me that the South American forest is probably geologically an ancient habitat that may have persisted without much change either in geography or climate for a long period of time. To be sure, no forest can be ancient in the sense that the sea is ancient; but in comparison with other terrestrial habitats (grasslands, alpine zones, temperate for-

ests), the South American forest may represent an unusually stable continuum. In this sense it is analogous with the tropical seas.

There certainly seems to be evidence that the tropical American forest has been stable for a sufficiently long time to permit the development of wide divergences in endemic groups, indicating to that extent that evolution must be an active process in this environment. The American monkeys perhaps form the readiest example of what I mean. They consist of two rather distinct groups, the marmosets and the cebids, but both are structurally different from all of the living Old World monkeys and from any known Old World fossils. The diverse types that are found in the forests of the American Tropics apparently evolved there from some primitive tarsioid or lemuroid ancestor. The cebid monkeys have achieved a remarkable range of specializations to life in the forest environment, involving structural changes that are distinctive enough to lead some mammalogists to put each type in a separate family (howlers as "Alouattidae," spider monkeys as "Atelidae," and so forth). The structural and physiological differences among these cebid monkeys are often clearly forest adaptations: the prehensile tail of many genera, the balancing tail of *Saimiri*, the thumb reduction of *Ateles*, the nocturnal adaptations of *Aotus*, and so forth. They all show a considerable development of that imponderable quality called "intelligence," though the intelligence of the New World monkeys must have developed quite independently of the intelligence of the Old World primates, perhaps from the common level of the rather backward lemurs and marmosets. The divergences in behavior among these monkeys are undoubtedly as striking as their divergences in structure, but except for Carpenter's classic study of the howlers, the American monkeys have been pretty much neglected by students of primate behavior. The measure of our ignorance is brought out in Hooton's recent survey of what we know about our poor relations. All in all, the American monkeys represent an amazing diversity of development, of "progress" in various directions, on the part of a phylogenetically homogeneous group within an apparently stable environment.

The radical adaptations of the Cebidae could be duplicated endlessly in the fauna and flora of the tropical forest; that the phenomenon is not confined to animals is shown by the range of habits, form, and physiological adaptation shown by the bromeliads. When I reflect on the exuberance of forms and the persistence of archaic, and sometimes apparently ill-adapted, types in the tropical forest, I am inclined to doubt the reality of anything comparable to a "struggle for existence" in the forests: it sometimes seems as though almost anything could survive, and as though almost everything has survived. But the diversity of the monkeys, and of many similar endemic groups, surely indicates a pervading evolutionary process within the forest environment; surely indicates a rich field for the exploration of biological processes. We have splendid marine stations for the study of the biology of the sea; similarly exact and painstaking studies of the forest might well give us a broadened comprehension of the nature of the forces governing adaptation and divergence, perhaps in terms that could be more readily interpreted through human experience, since so many of our primate characteristics seem to be products of our forest ancestry.

LIBERAL EDUCATION AND THE STUDY OF GOVERNMENT

By LANE W. LANCASTER

POLITICAL science as an independent discipline was not disentangled from history or "moral philosophy" much if any before the close of the Civil War. Since those early days when the study of the state and government was considered one of the "moral" disciplines, political science has moved in various directions, but the movement in general has certainly been away from the ancient tradition. Whether the direction of change has been desirable from the point of view of liberal education is the point of this inquiry.

The air today is full of disputation about the nature and content of liberal education, and it requires some hardihood to add to the clamor, the more so because we seem unlikely to unite on a definition of its meaning. There may perhaps be some agreement with the proposition that the object of a liberal education remains what it always was, namely, the production of a *kind of person*. That is, the primary supposition is that the persons to be educated are *ends* and *not means*. A free man is his own man; hence a liberally educated man is one who has cultivated himself and his intellect as values entirely independent of his vocation. A *trained* man may or may not be free in this sense, but if he is free it is not by virtue of his training but in spite of it. For it is the object of training to make him good *for* something, not simply good. The object is to develop a skill, not a quality, though the skill may in some sense be an element in quality. It was the *quality* of men that Mill had in mind when he reminded us that "it really is of importance, not only what men do, but also what manner of men they are that do it. Among the works of man, which human life is rightly employed in perfecting and beautifying, the first in importance surely is man himself."

A liberally educated man is one, I take it, whose mind has been so formed by his studies that he has learned to know the difference between a sound and an unsound proposition and to have a preference as among values which he can defend by rational argument. Perhaps what this comes to is the ability to read and to write and to think, and it may seem a somewhat trivial objective to those who assume that college graduates generally already have some facility with respect to these matters. That this is a rash assumption is well known to all who teach college students. Rare indeed is the student who uses language as if he were aware of the vagueness and ambiguities of words; few are those who have been taught the logic of language so that they comprehend the subtle and organic relationships between thought and expression. Yet people who have not learned these skills simply do not know what they are talking about. The result of such shortcomings in education is even more serious than inability to know the grounds of one's beliefs. Since one's fellow-students are for the most part in the same state there is literally no possibility of intelligible communication amongst such persons. And it follows that such students bring to the study of subject-matter no effective tools of understanding. If subjects in the curriculum make no contribution to this sort of understanding—to careful reading and precise writing—whatever else they may be, they can hardly be called liberal subjects.

Now it must be clear to anyone who studies the American college that the emphasis today is away from the liberal subjects and in quite different directions. Indeed so different are the current emphases that there are few who can even understand the notion that man is an end and not a means. Nearly every subject is now judged with no reference whatever to the contribution it may make to the forming of cultivated men and women, for the simple reason that most people apparently find it impossible to think of the quality of individuals apart from their "usefulness" in "society."

Two tests are commonly applied by those who tinker today so hopefully with the curriculum. The first of these is implicit in the blunt question, usually asked quite unashamedly, What can the student *do* with it? It is the application of this test, of course, which has depopulated classes in such "impractical" subjects as the classics, philosophy, and all but the most obviously utilitarian modern languages—"impractical" being, of course, a word used with a calculated disdain, intended to put educational "reactionaries" in their place. So respectable a subject as history is the latest victim of this demand that education be "practical." The current widespread demand for the compulsory teaching of American history has no discernible affinity with any idea of cultivating man's intellectual faculties; it is put forward as a device for making "good citizens," that is, as a way of forming a generation of Podsnaps, ready to follow blindly whatever leaders the whirligig of domestic politics may bring to the top.

The modern curriculum has suffered, in the second place, from a passion for what may be called "coverage." For some reason by no means clear it is believed that everything should be taught in the classroom, and that it is the principal business of instruction to supply information rather than to stimulate reflection and put students in the way of acquiring some humility. This itch is most evident in the field of the so-called social sciences where no nook or cranny is to be left unexplored in a vain attempt, to use the current cant, to "understand the world in which we live" or to "adjust ourselves" to other people. Examples are found in "survey courses" now so popular in "world history," "problems of democracy," "contemporary civilization," and so on. Even if such an enterprise were intellectually respectable as contrasted with more modest efforts to understand a *few* things by the student's own efforts, it is in any case Sisyphean, as is indeed admitted when its promoters clamor for new editions to keep them "up to date." Students must have information, but it will be of no avail if they do not know what to do with it when they get it. Even if it were the proper function of a college teacher to ladle out information, the teacher will not always be there. If the student learns how to read and *does* read, the information will be at hand when he needs it. And if he has been liberally educated he will bring to it intellectual habits which should enable him to extract meaning from it.

We are now ready to examine the present typical offerings in political science with these quite different tests in mind—the cultivation of the man as an end, the test of utility, and the test of "coverage." Let us begin with the last. In respect to this, the departments, at least where funds permit, have responded nobly. The world has been divided by the curriculum-makers both geographically and, of late, ideologically, so that we have not only courses in American government, British government, European, Oriental, and Latin American governments, but even the government of colonial dependencies. The phenomena of rule must be explored in every national setting from Iceland to Burma, from Kamchatka to Patagonia. The coming to power of such figures as Hitler and Mussolini created new opportunities for being "up to date," and college bulletins blossomed out with attractively-packaged courses entitled "Democracy and Dictatorship," and so forth—the content of both mouth-filling words being assumed clear and the dichotomy sharp.

But proliferation is not confined to government in general. Government in America is divided into numerous segments so that "coverage" may be complete. Thus we offer our students American national government, state government, municipal government, county and township government, and in some cases public administration on all three levels of government. In addition, there are courses in political parties, public personnel administration, public opinion, government regulation of business, constitutional and administrative law, jurisprudence, the administration of justice, and numerous offerings in international law and relations, comparative government, and political theory. Much of this atomization is due, no doubt, to the necessity of recognizing the vested interests of individuals. A part of it is traceable to what appears to be the

tendency of all institutions to expand their jurisdiction and keep their personnel occupied, each with his own specialty or crotchet. Otherwise it cannot be justified on any ground except that of furnishing information, "covering" the subject. That many of these subjects are primarily utilitarian seems to me to be beyond question.

The argument in favor of the utility of political science takes two forms. Those who teach it are able to say with justice that a knowledge of it is at least partial preparation for the public service. The claim has some cogency when made in behalf of such courses as public administration and its specialized subdivisions, though administration would seem to me to be an art rather than a science, and therefore better learned "on the job" than in the college classroom. These courses and those in special fields of public law seem to be definitely professional and to form, strictly speaking, no part of a liberal education. To me they seem definitely to belong to the upper division of the curriculum or to the professional institute where they might be pursued by persons who bring to their study some ability to deal with concepts and relationships.

The other argument for the "usefulness" of courses in political science is similar to that now being advanced for the study of American history. The subject is to be studied as a way of making good citizens. Somehow the student who knows such things as how treaties are negotiated and ratified, the content of the Monroe Doctrine, the city charter provisions for letting contracts, the organization of the state department of agriculture, the mechanism of the social security system, the party complexion of the House of Representatives, and so on, is expected to play a wiser and a better part in public affairs than one who has not been told about these esoteric matters from the rostrum. It is admitted that some of this information may be important, but possessing it has little or nothing to do with civic virtue. The thoughtful student who has pondered with Plato or Aquinas or Locke or Mill the perennial stuff of politics might just conceivably bring to public issues a wisdom denied to his fellows who has been stuffed with the contents of the latest textbook. Nor would the acquisition of information of this sort be beyond the ingenuity of any such student to whom it is necessary.

If the point of view here expressed is in any degree a reasonable one, then that portion of political science which might serve the needs of a liberally educated man is not far to seek. It will be found, I think, in those courses where the much despised principles and "theories" are discussed, where words are approached with caution and used with care, where the staple of talk is such terms as "justice," "equality," "law," "rights," "power," "State," "government," and the rest. No thoughtful student can grapple with such terms in the company of a serious and honest teacher without benefit to himself and in the end to the commonwealth. He will come from his studies less sure, and much less glib, but surely more humble and with the possibility of attaining in the fullness of time at least some of that unhurried wisdom without which no society can keep its health. Such a one can scarcely hope to be a governor or a senator or even perhaps a mayor, but he may come to see that Socrates was right when he said that there is a life higher than that of politics. It is only by producing more men and women who have grasped this truth that the state improves its health. No one has ever been made better by learning about government. In fact, our best informed people—who know far more about it than the professors—are the political bosses, who are certainly not models of civic rectitude.

All this is not to say that there is no place for information or "coverage" in a college course. Men obviously cannot think without facts and it will always be a part of our business as teachers to see that facts are available. Habits of extensive as well as intensive reading should be cultivated. But such habits may be formed without making every aspect of politics the subject of a course devoted to lecturing solemnly about matters well described in books available in the college library and easily mastered by students who have learned to read with discernment.

SCIENCE ON THE MARCH

HYBRID VEGETABLE SEED

HYBRID corn has been one of the great achievements of our time. Yields of corn have been greatly increased by developing widely divergent inbred lines and then recombining them in seed stocks. The mechanism by which vigor in hybrids is increased has not been thoroughly determined but the fact remains. A common example is the mule, derived from mating a jackass and a mare. In plants, greater yields result. No one has yet computed that hybrid corn has won the war, but there are so many delicate balances which determine the course and nature of so great an upheaval as a world war that it would not be surprising if someone did so—what with manpower shortages, food requirements, farm machinery needs, and the like.

Because of the excellent results with hybrid corn, it is natural that thinking should attempt to transfer hybrid vigor to other crops. Corn has the advantage in that the pistillate (female) flower parts, which develop into corn kernels, are located not only in separate flowers but also in parts of the plant separate from the staminate (male) parts. The latter are borne in the tassel at the top of the corn stalk. And so, two strains of corn which it is desired to cross may be grown adjacent and the undesired source of pollen may be removed simply by going through the field and cutting off the undesired tassels (de-tasseling). Corn pollen is wind borne, the cross is effected naturally, the ears of corn are taken from the de-tasseled stalks, and hybrid seed corn is the result.

With many economic plants, the problem is more difficult because the flowers are perfect, that is, both the staminate and pistillate parts are contained in the same flower. In order to produce hybrid seed in them, it is necessary to remove the stamens from the plants which are to be used as the female parent, and to hand-pollinate the emasculated flowers with pollen from the desired male plant. The labor and cost of hand emasculation and pollination are limiting factors. Eight to nine hours of labor have been required for emasculation and pollination of sufficient tomato flowers to produce an ounce of hybrid seed.

Geneticists, to meet the problem, have suggested a way of eliminating the tedious step of emasculation. They have thought in terms of developing plants which are by nature male-sterile, and using these as the female parent. In 1937 H. A. Jones and S. L. Emsweller of the U. S. Department of Agriculture reported a male-sterile onion, and in 1943 H. A. Jones and A. E. Clarke explained the inheritance of male sterility in the onion with particular reference to the production of hybrid seed, for which, incidentally, they received the Leonard H. Vaughan Memorial Award in Horticulture. By this process a strain of male-sterile onion can be developed which can be crossed, without emasculation, with pollen from an inbred male-fertile strain to produce hybrid onion seed.

Practical application of these predictions was made in 1944 by A. M. Binkley of Colorado State College in conjunction with H. A. Jones, and several lines of hybrid onions were grown from hybrid seed. Yields from some of the hybrids were less than from the non-hybrids, and most yields were in the same class with the non-hybrids. Yet one of the lots was significantly higher. When more inbred lines become available for crossing, combinations should be found which will greatly improve yields and yet have the other characters desired in a commercial onion.

The tomato seems the next vegetable likely to receive attention. In 1942 both K. C. Barrons and H. E. Lucas, of Michigan State College, and R. E. Larson, then at the University of Minnesota, suggested that male-sterile tomato plants might be utilized eventually as female parents in the production of commercial hybrid tomato seed. In 1944 T. M. Currence, of the University of Minnesota, reported on a semi-sterile type of tomato, the flowers of which had long styles which extended beyond the anthers previous to maturity and so reduced self-pollination. The character is simply inherited and may be transferred to any desired variety by back-crossing or by other types of breeding.

Following the same procedure as with the male-sterile onion, this strain may then be used as a female parent and hybrid tomato seed may be produced without the necessity for emasculation.

Some idea of what the general use of hybrid tomato seed might accomplish in terms of tomato production is shown by records from six states compiled by T. M. Currence, of Minnesota. Increased yields ranged from 19 to 52 per cent, with an average of 32 per cent. In other words, if a victory gardener can grow 3 bushels of tomatoes from 25 ordinary plants, he can produce an additional bushel from 25 hybrid seed plants. With 20,000,000 victory gardens in prospect, the possibilities are not minor—to say nothing of large commercial acreages. With increased production of foodstuffs now so important, the transfer of hybrid vigor to many economic crops will undoubtedly receive much attention.—H. B. TUKEY, New York State Agricultural Experiment Station, Geneva, N. Y.

AN EARLY TEXAN

IN July 1943 Dr. Cyrus N. Ray of Abilene, Texas, notified the Smithsonian Institution of the finding of a human skeleton in a bank of the Clear Fork of the Brazos River. The remains, uncovered by floodwaters, were 21 feet below the present valley floor. The burial gave promise of adding information on the nature of the people inhabiting that area at a relatively early period in New World history, and the writer was sent to investigate the discovery. In the interim Dr. Ray and his associates had removed the bones because the caving condition of the bank and the possibility of a new rise in the stream made their situation precarious. When the writer reached the site it was obvious that no changes had occurred after the disinterment and that the skeleton unquestionably had come from that location. Portions of the grave could be traced, several metatarsals were still in place at the back of the pit, and the lower half of a fibula which fit a piece obtained during the original digging was embedded in its floor. The fill at the back of the pit had not been worked out completely, and it was evident that an undisturbed series of strata, layers that could be followed without a break for a considerable distance up and down stream, had risen above it to the present surface. This demonstrated that the burial was not a recent penetration and that there had been a long period of alluviation in the valley, preceding the present channel-cutting era, after the body had been placed there. The circumstances of the find and the position of the body in the grave were reported subsequently by Dr. Ray and there is no need to repeat them here. ("A Texas Skeleton." *Science*, 98: 344. Oct. 15, 1943.) Such significance as attaches to the discovery is to be found in the nature of the deposits in which the skeleton occurred and in the bones themselves.

The earth in which the grave was dug and the overlying strata belong to a series of silts which have been designated Elm Creek[1] in one study and which are known locally as the Nugent. In general they indicate deposition by slack-water sheet floods spreading over the broad valley floors when conditions were much more humid than at present. A climate suitable to such phenomena seems not to have prevailed in the region since the closing days of the Late Glacial, the Wisconsin substage, or the pluvial period which in more southerly districts corresponds to it. Because of this some have considered the silts as Late Pleistocene in age. Other authorities maintain, however, that possibly the humid period here did not parallel the ice stage farther north but lagged somewhat and that the deposits attributed to it actually had their beginnings in Early Recent rather than in terminal Pleistocene times. In any case the fact that the burial was in the lower part of the silts places it fairly early in their formation and indicates that the individual was, at least, an Early Recent inhabitant of the area.

Unfortunately the skeleton was not in as good condition as might be desired and a number of bones, as well as portions of the skull, were missing. Enough survived, however, to give good indication of its general

[1] M. M. Leighton. Geological aspects of the finding of primitive man near Abilene, Texas (Preliminary report). Medallion Papers, No. XXIV, Gila Pueblo, Globe, Arizona.

characteristics. The bones were first sent to Dr. Harry L. Shapiro, Chairman of the Department of Anthropology of the American Museum of Natural History, New York, and then were submitted to Dr. T. D. Stewart, Curator of the Division of Physical Anthropology, U. S. National Museum, who spent several months in an effort to reconstruct the skull and doing as much repair as possible on other portions of the skeleton. Both prepared statements on their observations, the gist being that the individual was a male, about 40 years of age at the time of death, and that while certain characteristics suggest a modern Indian others are similar to those present in the more primitive forms of neoanthropic man found in America. Both agreed that the skeleton could be that of an early Indian, hence there would be nothing anachronistic in its being found in deposits of Late Pleistocene or Early Recent age.

In commenting on other crania from deep burials in the Abilene region, although none came from as old an horizon as the present example, Dr. E. A. Hooton of Harvard University several years ago expressed the opinion that they exemplified a very primitive type of American Indian and probably represented one of the earlier strata in the American population. He also stressed the fact that, while they were a morphologically modern type, it was not impossible for them to date back to the end of the Pleistocene as physically modern types of men were in existence in the Old World before the end of the Glacial Period. Late Pleistocene crania quite similar to those from Texas have since been reported from China, and as it is generally believed that the New World was populated by migrations from northeastern Asia, it is significant to know that modern types of man had a respectable antiquity in that region. However, Hooton, Shapiro and Stewart agree that it is impossible to prove antiquity from the nature of the bones alone and that the age of such remains must be determined by that of the stratum in which they are found. In the present case the deposits containing the skeleton seem to be Late Pleistocene or Early Recent geologically, and this suggests that the burial may have been made 8,000 to 10,000 years ago.

As there were no funerary offerings in the grave there is no way to correlate the remains with any of the known cultural horizons—such as Folsom, Sandia, Abilene, or the Cochise—which date from about that period. Although a small piece of worked stone was found in the dirt taken from the pit, it is too fragmentary to be certain of the type of implement represented. The flaking technique is an early form, but it is not sufficiently distinct to indicate cultural affinities. Subsequent floods may eventually uncover a similar burial accompanied by artifacts showing the cultural group to which the individual belonged. Until they do, however, it is not possible to say which of the various kinds of stone tools found in the region were made by individuals of the type represented by the present skeleton.—FRANK H. H. ROBERTS, JR., Bureau of American Ethnology, Smithsonian Institution, Washington, D. C.

WAR MINERALS—MICA

MANY adults who obtained their elementary education in rural environments became familiar with mica as an isinglass used for windows in stoves and other heat-producing devices. Mica has unexcelled transparency and heat resistance for such use. It is chiefly important, however, in modern industry because of its high dielectric strength. Other useful characteristic properties include flexibility, toughness, and low heat conductivity, as well as its inertness to high temperatures. Because of its peerless dielectric quality, mica was early recognized as most essential to the successful prosecution of this war of machines containing electrical units. When our chief sources of foreign supply were almost cut off soon after we entered the war, it was moved to the top of the list of most critically needed materials. It still remains in that position.

Mica is a group of closely related minerals. As used here, the term applies only to muscovite, the transparent "white" mica. Muscovite is a hydrous compound of aluminum, silica, and potash. The amber mica, phlogopite, also contains magnesium. It has certain war uses. Biotite, the dark-green to black mica, containing additional iron, is of slight industrial use.

Mica is used in almost every type of electrical apparatus, including familiar household and industrial appliances. It is an indispensable material in countless generators and motors. Condensers, magnetos, and radio tubes in instruments and machines for military use require mica of the highest quality. It is extensively used in telephones, radios, and radar apparatus. Airplanes could not fly at war speeds and under combat conditions without high-grade mica in the magnetos and spark plugs. High-speed communications along the battle fronts and around the world could not function without it. Mobile mechanized warfare of the superior winning type without mica would be scarcely more than a dream of some master strategist.

Mica of military grade must be free of structural imperfections which would cause it to split unevenly. The rived cleavage films, or "splittings," may be as thin as one-thousandth of an inch although some are nine times as thick. Mica must also be free of mineral inclusions which would reduce its electrical resistance. These rigorous specifications are imposed by highly specialized uses under all types of war environments. Mica is the separator film between the plates of magneto and radio condensers. Certain elements of radio tubes for war use under a wide diversity of stresses must be composed of it. Cigarette films and nose washers in airplane spark plugs require mica of the highest dielectric quality. Other uses of mica in war machines and apparatus do not require such stringent specifications. Phlogopite block mica is used extensively for the manufacture of spark plugs. Most of it is obtained from Madagascar, with small stocks coming from Mexico and Canada.

A wartime research project of high scientific interest and economic importance was developed by the Bell Telephone Laboratories under the sponsorship of the National Research Council. It resulted in the production of mica testing equipment whereby imperfections in the mica sheets can be readily and promptly detected. As one result, it has been found that lower grades of mica could be more extensively utilized.

Mica has remained in the background of public knowledge of the minerals which are winning this war. It is less well known and less dramatized than petroleum and the metals. Attempts were made, as the shortage grew serious, to manufacture substitutes but so far none has replaced much of the muscovite used in electrical apparatus and machines for war use. Glass and ceramic materials have been used in condensers, but paper is the chief substitute for mica. More ceramic insulation has recently been used in spark plugs. It has been predicted that substitutes will not replace more than fifteen per cent of the essential mica.

Mica is a common mineral in many rocks of the earth's crust. It is abundant in most of the old crystalline rocks which underlie the Appalachian Piedmont province. Similar old mica-bearing rocks are found also in the core of the Black Hills and in the interiors of most large ranges in the Rocky Mountains and in the Sierra Nevada. Sediments originally derived from the decay and disintegration of these micaceous rocks have been consolidated in widespread layers of sandstone and shale which contain numerous flakes of shiny mica scattered among the gains of sand and silt. Sands along the channels of streams which head among or flow through mica-bearing rocks glisten with abundant flakes of mica.

If mica is thus naturally so abundant, why should it be so scarce for war use that it ranks at the top of the list of strategic minerals? The answer is quality. Mica for use as a dielectric in most war machines and apparatus must be clear and free from flaws. It is essential also that the mica occur in masses—crystals or books—sufficiently large that sheets not less than one inch square can be split from them. Sheets several inches square are also in great demand. Books yielding the largest sheets of mica are the most valuable as well as being relatively rare. The need for the large sheets of mica in the large condensers has recently slackened somewhat as condenser sizes have been decreased and as some substitutes for mica have been developed for use in the larger sizes. Muscovite splits readily into thin sheets and laminae because upon crystallization from magmatic solutions it develops

perfect basal cleavage as a result of a sheetlike arrangement of the molecules within the crystal.

Mica in large crystals and books is not found in common micaceous crystalline rocks. The best quality of muscovite in masses sufficiently large to obtain sheets one inch to several inches square occurs only in pegmatite—a very coarsely crystalline igneous rock which roughly resembles coarse-grained granite. Most pegmatites are composed of an assemblage of large crystals of quartz, muscovite, and feldspar. Some contain rare industrial minerals, such as beryl, topaz, spodumene (lithium-bearing), columbite, and tantalite. In general, pegmatites are long, relatively narrow, and pinch and swell erratically in all dimensions. They were formed as dikelike offshoots from cooling masses of molten rock (magma).

Mica crystals of huge size have been found in some pegmatites. A single crystal weighing more than two tons has been reported from North Carolina. A crystal reported from India was even larger. It measured ten feet across the base and fifteen feet in another dimension.

Prior to this war, most of the mica of highest quality in world commerce was obtained from India, with subordinate amounts from South America. A large factor in those sources of supply is the relatively low cost of the hand labor required for all phases of mica mining and preparation for market. Indian laborers, for example, split three to four pounds of mica a day, at a rate equivalent to three cents a pound. In 1943–44, approximately three-fifths of our high-quality muscovite was imported from India. About one-fifth came from Brazil. Small amounts were obtained from other South American countries, Africa, and Canada. Much of the mica obtained from India for war use is carried by air transport, mainly as ballast in returning cargo ships. As much as fifty plane loads have been delivered in a month.

Domestic war production of mica is principally from North Carolina, in the crystalline rocks of the state. Other Appalachian producing states include Virginia, Georgia, and Alabama. Most of the New England states are mica producers under the stimulus of war prices. The Black Hills of South Dakota are the third largest domestic producer. Some mica for war use is obtained from several western and southwestern states. The number of mines in actual production during the war is probably several hundred, with the number having more than doubled within the past two years. Domestic production has increased many fold during the war. Imports have likewise been increased to keep pace with the accelerated needs for highest quality mica in airplanes, radio apparatus, and other first-line war machines. The latest available information indicates that the crisis in regard to high-grade mica has been overcome and that supplies on hand and in sight will probably meet foreseeable requirements.—ARTHUR BEVAN, Virginia Geological Survey, Charlottesville.

SILVER SAVED NEW BURMA ROAD

A REMARKABLE story of ingenuity and resource has just been told by S. F. Benton, British scientist in India. This is how essential pure water was supplied to the 30,000 native laborers rushed up to Assam in March 1942, against the threat of the Japanese advance, to work on the celebrated new Burma Road.

Without pure water the situation, militarily would have been very grave. Three of the world's most deadly diseases, bacilliary dysentery, cholera and typhoid, are mainly transmitted by polluted water.

The neighboring rivers are all badly polluted by the villages of the local Naga tribes, and dysentery broke out among the laborers as soon as they reached the construction site. Moreover, cholera was already prevalent among the Nagas, and the medical officer with the laborers warned that if sterile water supplies were not available before the opening of the cholera season with the early rains of mid-April, half the labor force might be lost, and the Manipur Road closed.

Obviously pure drinking water daily for 30,000 men could not be provided by boiling, and filtration on the scale required was impracticable and not sufficiently reliable. Moreover, since the laborers greatly dislike

the taste of chlorinated water, it was probable that even if chlorinated water were provided, they would still have preferred to drink the polluted stream water.

Hence, a fourth method, only just emerged from the research stage, was adopted. It involved treating the water electrolytically with silver. One part of silver in 100 million parts of water will effectively kill all bacteria. Exactly how it works is unknown, but it is believed the silver replaces some other metal in the water, essential for the breathing of the bacterial cell.

All that is necessary for sterilizing water in this new way is a small direct current and two silver plates. A current flow of only 10 milliamps is sufficient to treat 1,000 gallons of water an hour. At the start the only source of current Mr. Benton had was 4.5 volt flashlight batteries, and the complete stock, 125, in the little village of Jorhat, was bought up. Four batteries were connected up and placed on a piece of wood which was floated on top of the water in the tarpaulin tank. The batteries were wired to two small silver plates 4 inches square, projecting under the wood into the water.

Twenty minutes of this electrolytic treatment sterilized the 3,000 gallons in the tarpaulin tank, and a set of four batteries was capable of sterilizing 36,000 gallons of water a day. By mid-April, there was a daily total output of 100,000 gallons of sterile water. So far from dysentery increasing, it actually decreased.

When the stock of batteries had fallen to two, 50 car batteries arrived from Calcutta. The floating sets were converted to these by using a flex, kept taut to the floating wood with its silver plates by a bamboo used like a fishing rod.

The final stage in this remarkable story is the devising of automatic sets to sterilize water. As the water was pumped into the tank, the stream from the pump completed the circuit, so that when the water stopped flowing, the circuit was automatically broken.—H. SHEPHERD.

BOOK REVIEWS

SCIENCE IN SOVIET RUSSIA

Science in Soviet Russia. Papers presented at Congress of American-Soviet Friendship under auspices of National Council of American-Soviet Friendship. 97 pp. 1944. $1.50. Jaques Cattell Press, Lancaster, Pa.

THESE short papers were presented at the Congress of American-Soviet Friendship held in New York City on November 7, 1943, and are now published under the auspices of the National Council of American-Soviet Friendship. While these little informal reports on various phases of Soviet science and technology are very uneven, they are strikingly uniform in their expressions of enthusiasm for the recent accomplishments of Soviet scientists.

Doctor Cannon emphasizes in his preface that while the Soviets have stressed the social value of scientific research, "there has been no sharp restriction of research to practical ends." All the contributors to the symposium agree with Doctor Cannon that the Soviets appreciate that "investigation into the basic sciences and into questions of theory are likely to have large, unfolding influences revealing vast new vistas of understanding and that this fresh understanding may have supreme human values."

The essays in the volume include Sir Hubert Wilkins on Soviet Exploration and Geography; V. K. Zworykin on Soviet Developments in Electronics; S. W. Muller on Geology and Related Sciences; C. O. Dunbar on Geology and Mineralogy; C. E. Kellogg on Soil Technology and Agriculture; L. C. Dunn on the Biological Sciences; S. Waksman on Bacteriology; A. W. Curtis, Jr., on Relations of Soviet Science and Democracy; W. M. Stanley on Viruses; V. Lebedenko on Military Medicine; W. Penfield on The Recent Surgical Mission to the U.S.S.R.; Hugh Cabot on Russian Medicine Organized for War; C.-E. A. Winslow on Public Health, and Alice Hamilton on Industrial Medicine.

Doctor Stanley's description of Soviet studies on viruses is particularly interesting, since it is carefully documented and describes the brilliant work of D. Ivanovski in 1892 and later in 1903 on the tobacco mosaic virus.

It would seem that a more comprehensively prepared and well-documented survey of current science in Soviet Russia would be well worthwhile. This little 97-page volume is an admirable appetizer for such an effort. Certainly the work of the National Council of American-Soviet Friendship and the American-Soviet Medical Society deserves support from American scientists. It would help us greatly to have a thorough understanding of what Soviet scientists are accomplishing. It would be wise for us to do everything we can to promote a greater degree of exchange of scientific ideas between our Russian colleagues and ourselves.—CHAUNCEY D. LEAKE.

JOSEPH LISTER

Joseph Lister, Father of Modern Surgery. Rhoda Truax. 287 pp. Illus. 1944. $3.50. Bobbs-Merrill Company, Indianapolis.

LORD LISTER needs no introduction. Millions know who he was and what he did—even as they know who Darwin, Huxley, Pasteur, G. B. Shaw are or were and what they did. But the story of his life is not perhaps so well known. It now will be, for Miss Truax has written a story which will be read for its readability, its dramatic interest, as well as for its sound facts concerning the life of the great man who is its hero. It seems to the reviewer that this present volume is a rare instance of a book which, while being really spectacular and striking, is at the same time not cheap or trivial. The text is well written, combining description, extracts from letters and speeches, narration, and plentifully interspersed with dialogue which makes it very much alive indeed. The chapter headings in the Table of Contents alone would tempt one at least to *begin* the book:—The Godless College, The Killer in Glagow, Presenting the Evidence, The Discredited Ligature, Progress, Storming the Citadel, The Long Honeymoon—do not these read like the chapter headings of a thrilling story? They do! Nor is the story which they introduce less thrilling than the headings. Try it, you readers who like tales of advances in surgery against intrenched opinions, against prejudice; you readers who like the fascinating story of a strong, fearless, yet God-fear-

ing man, who knew he was advancing the cause of suffering mortals; you readers who like a rattling good biography anyway, full of dialogue, full of fire, the scenes laid among the academic and "medicinal" circles of England and Scotland. The style is excellent, the vocabulary rich and full—no straining after unusual effects, a clear tale well and interestingly told. There are nine half-tones of portraits and places. Would that there could have been more! A magnificent portrait of Lister faces page 264. To meditate long and earnestly upon this splendid face is to feel one's whole nature being rectified, ennobled.

"Honors and degrees piled up, until he was in possession of some eighty or more diplomas and certificates from nineteen different countries." He was made Baron Lister by Queen Victoria (upon whom he had operated); was shaken by the hand by King Edward VII, who said, "Lord Lister, I know well that if it had not been for you and your work, I would not be here today." Many others could say the same. Even finer than all this was the tribute paid to him at a dinner in his honor given by the Royal Society. Our then ambassador to the Court of St. James, Mr. Bayard, said, "My Lord, it is not a *profession,* it is not a *nation,* it is HUMANITY ITSELF which with uncovered head salutes you!"

Since human beings learn most easily by imitation, we therefore ought to read the biographies of good men and women; one of the best gifts of science to our race is the lives of the devoted scientists through whom scientific progress has come. Good old Longfellow was eternally right when he said:

> Lives of great men all remind us
> We can make our lives sublime,
> And, departing, leave behind us
> Footprints on the sands of time.

—LEON AUGUSTUS HAUSMAN.

SOCIAL DARWINISM IN AMERICA

Social Darwinism in American Thought, 1860–1915. Richard Hofstadter. 191 pp. 1944. $2.50. University of Pennsylvania Press.

WE have here a careful survey, marked by a fairmindedness and objectivity that reflect much credit upon the author. He cites nearly all the writers whom this reviewer has ever heard of—good, less good, and least good—who have touched, even peripherally, upon the "ism" in question. Of its kind, this small volume is of high quality.

Some of us are not "ismic" enough to take much interest in doctrines and doctrinaires, in labels, in "schools of thought." But that is another story, for some other time. There are plenty who like to know what a lot of writers have thought, whether or not the ink-spillers have demonstrated any right to an opinion; and that audience will be given, in a clear and acceptable manner, what they are looking for.

The sections on "The Coming of Darwinism," on "The Vogue of Spencer," and on "William Graham Sumner: Social Darwinist," are above the average in tone and judgment, though this reviewer would not consider Sumner an "ist" of any kind except a scientist. If he had any "ism" at all, to cover it the term "scientism" would have to be coined—only that that affix would cancel the stem-word. For "isms" belong to philosophy. Science deals, not with tenets but with hypotheses, not guesses or intuitions—with inductions from masses of data, with tentative conclusions not held emotionally, always under verification, never promoted into articles of faith.

The reviewer is on record as to Darwin, Spencer, and Sumner. It is a pity that Darwin was ever forced into traveling what he calls "a path unknown to me and full of pitfalls," in those chapters of *The Descent of Man* which attempt to deal with morals; for he had there no such mass of concrete evidence as he inveterately demanded elsewhere, but only "the advantage of previous discussions by able men." (Letter to Morley, March 24, 1871, in F. Darwin, More Letters of Charles Darwin, I, 324.) Reckless recourse to the "argument from analogy" by indiscreet adherents had started an "ism" which worried him and led him to try to mend matters. It is this "ism" that most of the hallelujahs and wailings have been about.

Then came Spencer, intent upon an all-covering philosophical formula and with the prime idea of working up to a system of ethics. Also with the misleading phrase, "survival of the fittest," which Darwin

adopted in his docile and impressionable humility. No one wants to belittle Spencer, who accomplished a colossal project under heavy handicaps; but it is only fair to say that Spencer had to be forced to gather raw materials, in his *Principles of Sociology*, because there were few antecedent "discussions" over bodies of facts to which to apply what Huxley called his "diabolical dialectics." One might add that it seems risky to attribute Spencer's vogue, in this country or elsewhere (as in Japan), to anything else than his more than implied idea that evolution means progress, instead of merely adjustment—which looks progressive or retrogressive according to the viewpoint occupied by the observer.

These comments are evoked by the general excellence of Dr. Hofstadter's first two sketches; otherwise there would be no reason to review him. And I think that Sumner is treated with unusual fairness, though to attribute to him what he called "filosofy" is to risk his resentment, if he is still aware of sublunary things. What has been written about Sumner has been usually emotionally enthusiastic in either its love or hate; but this author is discriminating. However, can a man be a Social Darwinist if he denies the presence of evolution in the superorganic realm? This is, of course, no place to expatiate on such matters; nor could the author expect to cover all such aspects in the fourteen pages allotted to Sumner—or in the sixteen accorded to Darwin or the nineteen to Spencer.

This reviewer has estimated elsewhere a number of the other sociologists cited by the author. I used to know and like personally most of the now deceased gentlemen named in succeeding chapters. I do not recall that any of them was a fervent Darwinist or the reverse. Ward was all for education, in his kindly way, believing that environment largely made or unmade the man; also for the defense and enlargement of woman's prestige. Some of Sumner's contemporaries were horrified at his realism and accused him of a cold-hearted indifference to Uplift. Giddings used to trade smart slaps with the historians: when they alleged that sociology was a brazen steal from history, he replied that all that was of consequence in history was revealed by sociology. Small was always tinkering up methodological gadgets.

There was once a session of the American Sociological Society devoted to Social Darwinism; but nothing emerged from it, not even a diverting squabble, that was lively enough to stick in memory. It struck my youthful inexperience at the time that these elders in Israel were thinking of a variety of things, rather irrelevant to Darwinism, which they rather took for granted. None of them went in for any such vociferous and belligerent discipleship as did Jack London, or any such hostility as did William J. Bryan. I judged that nearly all of them would have registered as evolutionists, and would have interpreted what they disliked as perversions of evolution as they saw it.

These personal impressions are for what they may be worth. Concerning later writers, with whose works I am only indifferently familiar, I can say only this: that Dr. Hofstadter's treatment of those I know something definite about predisposes me to trust his account of those whom I know only sketchily. That, to my mind, is a kind of accolade. It seems to me rather wonderful that he could have condensed so much into such limited space.—A. G. KELLER.

HERPETOLOGY OF THE CHICAGO AREA

Amphibians and Reptiles of the Chicago Area. Clifford H. Pope. 175 pp. Illus. 1944. $1.75. Chicago Natural History Museum.

UNDOUBTEDLY mindful of enhancing the service of the Chicago Natural History Museum to the interested lay public, Mr. Pope has published recently this attractive volume on the Amphibians and Reptiles of the Chicago area. It is one of a number of similar handbooks issued in recent years, in response to a growing interest in these groups on the part of the public throughout the country.

Paper bound with a striking figure of a tiger salamander on the front and rear covers, this book presents its material in a way that should stimulate its readers to delve into its contents. The author's aim is "to arouse interest in reptiles and amphibians by showing that each kind has its own habits, worthy of special and detailed attention."

The Chicago area includes fifteen counties in Illinois and Indiana, one in Michigan and

three in Wisconsin, off the southern tip of Lake Michigan, and at no point more than seventy miles distant from the Chicago Museum. This is a transitional zone between the hardwood forest and prairie, occupied by 21 species of amphibians and 31 species of reptiles, of which certain species found to the west are unknown farther east and vice versa.

Each of the 52 species found in this area is discussed, with separate paragraphs devoted to recognition characters, sex differences and behavior, reproduction, habits, food, habitat, economic importance and occurrence in the area. Many species are illustrated, in photographs or line drawings, with respect to adults, nests, egg masses, or habitat scenes. The colored plates, reproduced from paintings by Leon L. Pray and Albert A. Enzenbacher, are an attractive addition to the keys and descriptions and aid in precise identification of various salamanders, frogs, snakes and turtles. Miss Peggy Collings' drawings of salamanders, D. Dwight Davis' photographs of snakes, and Mr. Pray's black and white drawings of frogs and toads add to the profusion of illustrations.

While this volume should admirably fulfill its objective in making available an accurate natural history account of the amphibians and reptiles of the Chicago area, to the herpetologist, for whom it was not meant, there are several features left to be desired—specific locality records, more distribution maps, exact citations to literature and a more adequate bibliography. However, as it stands, Pope's volume has much to commend it, and it should find its place on the bookshelf of every serious-minded student of amphibians and reptiles.—JOHN W. PRICE.

A COUNTRY SURGEON

Ventures in Science of a Country Surgeon. Arthur E. Hertzler, M.D. 304 pp. Illus. 1944. Published by author, Halstead, Kansas.

THIS little book has been written by the author of *The Horse and Buggy Doctor,* (Harper, 1938) and *The Doctor and His Patients,* (Harper, 1940) and to some degree, it is supplementary to these well-known volumes. The subject-matter of this latest book comprises a continuation of the above already published record of the professional experiences of its author. It is somewhat anecdotal in character and is interspersed with numerous philosophical meanderings. It is packed with information, much of it valuable and all of it interesting, and, though the chapter headings are severely technical, the subject matter thereunder has been presented in a form sufficiently popular to make it good reading, even for nontechnical readers to whom the adventures or the opinions of the author ordinarily would be of merely casual interest. Indeed, there are presented with marvelous tact and restraint a series of word pictures, humorous or pathetic, and there has been manifested an insight and a sensitiveness to atmosphere and a sympathy so deep with frail human nature, that the good doctor cannot keep his emotions off the printed page. It becomes increasingly evident, as one reads, that a considerable part of a physician's time is taken up—or, more correctly, is wasted—over the troubles and predicaments of a lot of people "who ought to know better."

It is regretted that space limitations forbid inclusion here of quotations from some of the more outstanding of the author's stories and experiences. They are excellent examples of adroit writing. Difficult things are put forth with remarkable clarity and conciseness; descriptions of the usual are expressed in a manner unusual, and, as presented, there is nothing trite or hackneyed about the most ordinary and commonplace. The book as a whole is an excellent illustration of what William Lyon Phelps has somewhere said that it is "never the subject, but always the style that determines a writer's final rank."

Founder of the well-known Hertzler Memorial Hospital, Halstead, Kansas, he has conducted special researches in diseases of the peritoneum since 1894 as well as special investigations as to local anaesthesia and diseases of the thyroid gland—yes, on the whole, a rather unusual "country" doctor!

Perhaps the central theme of this little book may be epitomized in the quotation from its title page: "Medical science has brought to mankind the gift of longer and healthier lives. Therein lies a challenge to all mankind to do its share in making life happier, richer and nobler."—J. S. WADE.

EDEN RE-DISCOVERED

That Vanishing Eden: A Naturalist's Florida. Thomas Barbour. 250 pp. Illus. 1944. $3.00. Little, Brown & Company, Boston. An Atlantic Monthly Press Book.

NATURALISTS should enjoy Dr. Barbour's latest book because it describes in an interesting and accurate manner one of the few subtropical regions within the continental limits of the United States. The author has been an intermittent resident of Florida for the past 50 years, and his description of its flora, fauna, and other natural characteristics reflects his first-hand knowledge of these matters. The book is a very readable volume, even for those who despair at the naturalist's viewpoint, and it should be read by everyone interested in this tropical wonderland.

The author discusses Florida from the naturalist's point of view, which, in this case, happens to be as it was a number of years ago before Americans owned Model T's and could get about and carry out the processes of civilization. Much of the descriptive matter centers about Florida of thirty or more years ago, when Dr. Barbour camped, fished, and hunted in what was then a wild, yet peaceful land. He discusses the plants and animals which form the ancestral background of those we find today, and then reviews briefly the present flora and fauna, with predictions as to future trends unless some conservation is practiced.

Dr. Barbour's description of the beaches, deep woods, springs, and other natural features is fascinating, yet accurate. The old shell mounds created by the culinary practices of many generations of Indians rate high in general interest, although they might seem to border on the historical rather than the natural side of the picture. The present-day Seminole Indians receive the author's sympathy, and he feels the State's magnanimous gesture in issuing the Indians free license plates for their cars is not sufficient atonement for our unspeakable behavior towards them.

The glowing account of the old days when hunting and fishing were so good as to be almost boring, may surprise and arouse the envy of present-day sportsmen. Traveling in an old Model T, the author's party often toured the piney-woods in quest of bass and game. At one point, they ran their seine through a roadside ditch and "—in no time we'd have half a dozen two- or three-pound bass flopping about on the sand of the roadside." There will be those who have tried this trick in late years and who considered themselves fortunate in bagging a few top minnows.

The author gives some timely advice to residents of Florida to develop their state as befits a locality with so many natural blessings. It is to be hoped that something can be done to erase the resort attitude which spurns conservation because no one plans to stay for long. However, the reviewer is not in favor of giving the state back to the Indians, nor to the giant sloth. And he personally feels little concern for the many snakes and skunks killed along those magnificent highways. Naturalists to the contrary, it would seem that we ought to favor a certain amount of evolution and civilization, at least enough to bring the human race up to the point where men can wear white collars and read books.

The author feels that much of Florida has been "devastated," but is it not possible to consider large acreages of golden oranges and green celery as a pleasant diversion from endless tracts of tangled forests? The practically minded may take exception to the all-out naturalist attitude of the author, but will end by frankly admitting that Dr. Barbour has written a good book.—M. C. SWINGLE.

THE ROYAL SOCIETY, 1660–1940

The Royal Society, 1660–1940. Sir Henry Lyons. 354 pp. 1944. Cambridge, at the University Press; New York, The Macmillan Company.

SIR HENRY LYONS, for many years treasurer of the Royal Society, was in virtue of his office, interests, and administrative experience, the ideal man to write the present volume. It is sad to have to record that he did not live to see its publication.

The book provides an illuminating account of the manner in which "the famous Academy of . . . philosophical scepticks that believe nothing not tryed"—as a gentleman later to become its President called the Royal Society—conducted and administered its various affairs. In addition to this the book

gives one an insight into the growth and development of the Royal Society which does very much more than supplement the more purely earlier historical accounts of that admirable institution.

The management of a scientific society's practical affairs bears a not insignificant relation to the realization of its potentialities for survival and the performance of labors both beneficial and useful. In the conduct of its affairs the Royal Society does not always appear to have been well-advised, but on the whole it seems remarkable how well and efficiently it has been served in this respect by its officers. Sir Henry Lyons writes most interestingly of the ups and downs of the Society's fortunes, and from his account many a valuable moral could be drawn, among the chief of which I should say is: Place not your societies' fortunes in the hands of business men. Another moral to be drawn is: Admit not too many non-scientists into your midst, but let a scientific society be a scientific society, and not a society for the encouragement of donors who usually don't donate, anyway.

There are very few questions which the reader is likely to ask which Sir Henry leaves unanswered. His excellent work will for many years serve as a valuable repository of information concerning an aspect of the history of the Royal Society which has never before been adequately treated.—ASHLEY MONTAGU.

AQUARIUM HANDBOOK

Guide to Higher Aquarium Animals. Edward T. Boardman. 107 pp. Illus. 1944. Cranbrook Institute of Science, Bloomfield Hills, Mich.

A GOOD first impression, made by the excellent typography, binding, and illustration of Mr. Boardman's book results in a considerable disappointment after critical examination. The organization is rather that of an identification list of Michigan fishes, salamanders, frogs, turtles and snakes, quite erratically chosen, and in many cases without evident suitability for the aquarium. No distinction is made between the aquarium and terrarium, although many of the creatures listed are wholly terrestrial. The more interesting, cleanly, and handsome snakes for the terrarium are omitted, while the partly aquatic but evil-smelling water snakes and garter snakes are listed. The box turtle is omitted, though no more terrestrial than is the common toad, which is included.

The difficulty of avoiding minor errors, even for a scientific press, is illustrated by the failure to adopt the excellent distinction between the plural forms "fish" and "fishes." The reviewer especially dislikes the continued use of the term *Anura*, which has not had much taxonomic respectability since 1907. The figure intended to represent the spotted salamander is a typical midwestern tiger salamander. The specific name of the bullfrog is misspelled and capitalized. The soft-shelled turtle is said to lack bony plates, and the cutting edges of the jaws in turtles are said to be on the head.

There is a need for a renewed effort to produce aquarium and terrarium handbooks directed to the beginner and filled with instruction as to the establishment and management of various combinations of animals in these two types of vivarium. Such vivaria offer an extremely important aid to the parent whose children exhibit an interest in natural history, and equally to the grade school science teacher and the high school biological laboratory.—KARL P. SCHMIDT.

COMMENTS AND CRITICISMS

Apology to Dr. Remmers

We have discovered that we made an error in the legend of Figure 4, page 296, of the April issue of THE SCIENTIFIC MONTHLY. We very much regret it and will do anything which you think should be done to correct the mistake.—PRINTER.

Occasionally errors will be made in spite of all precautions, and when we make them we must grin and take the consequences. The legend should have read: "Proposition: 'Negroes should be allowed to enter trained occupations on the same basis as white people.' Appreciable shift indicated."—ED.

Meteors and Meteorology

Dorrit Hoffleit's "What Falls from Heaven" in the January 1945 SCIENTIFIC MONTHLY has given me much pleasure, and I am writing partly to say how glad I am that you have printed this unusual paper.

The research on the temperature of the high upper atmosphere by Lindemann, based on the precise observations of the altitudes at which meteors are ignited and extinguished, has I regret to note, been omitted from Dr. Hoffleit's survey. This work is noteworthy for its originality as well as for the connection between meteors and meteorology.

As for Dr. Hoffleit's introductory remarks about the etymology of *meteor* I am like a character in Fibber McGee and Molly's program. "That is not the way I heered it." Reference to Liddell and Scott's Greek-English dictionary shows that Homer used "meteoros" to mean "high" and "raised up" as in "high horse," "high wave," "a bag of meal *raised up* and tossed onto a wagon." Reference to Webster's Dictionary shows that its etymologist interpreted this as indicating derivation of meteor from *meta*, beyond, and *aeiro*, raise.

According to John Burnet, *Early Greek Philosophy*, the early Greek scientists, Thales, Anaximander, *et al.*, were primarily interested in cosmogony, and erected "meteor" into a *generic* for all phenomena in the heavens, *e.g.*, comets, milky way, shooting stars. As their interests widened the use of *meteor* was expanded to include "all the affections common to air and water, and the kinds and parts of the earth and their affections," to use the words of Aristotle.

Aristotle, in writing his *Te Meteorologica*, restricted its scope to phenomena "below the moon," (*Meteorologica* 338B line 23), although his knowledge of astronomical distances was insufficient as shown by his retention of the milky way, comets, shooting stars, etc., in the *Meteorologica*.

Skeat's etymological dictionary shows that the application of the word "meteor" as a *specific* to shooting stars is an Anglicism committed by unimpeachable authorities. Other European languages generally use *meteor* in the generic sense of the ancient Greek, and call the subject of Dr. Hoffleit's paper "bolides" or "shooting stars," *e.g.*, French, "étiole filante."

Meteorologists, the etymological foundations of whose science have been eroded by this English trope, could recover the lost ground by systematically using the word meteor according to the ancient usage, of which enough persists in such expressions as "juvenile and meteoric water," "hydrometers," and the like.—ERIC R. MILLER.

Galileo vs. Aristotle

In his essay, "The Autonomy of Science," [February 1945 issue of THE SCIENTIFIC MONTHLY], M. Polanyi retells the well-worn story of Galileo dropping weights from the leaning tower of Pisa to disprove Aristotle's "teaching that . . . bodies fall at different rates proportional to their weights," [p. 146].

I got the impression rather distinctly from reading Professor Lane Cooper's very interesting and scholarly little book, *Aristotle, Galileo, and the Leaning Tower of Pisa* (Ithaca, 1935), a few years ago that (1) Aristotle never claimed that "bodies fall at rates proportional to their weights" and (2) that there is very little evidence, if any, to indicate that Galileo ever did perform such an experiment. As Cooper says:

". . . whatever Galileo did, or failed to do, at Pisa, in all his extant writings he never once mentions the leaning tower, and never talks of experimenting from it," [p. 14], and

"And now we come to a rather cogent proof from Galileo himself that he did not while teaching at Pisa make the alleged experiment from the leaning tower," [p. 53].

Is Lane Cooper's study sufficiently comprehensive and correct? Have I misinterpreted his reasoning and conclusions? Or, is this story of Galileo *vs.* Aristotle just another tale out of the scientist's Mother Goose? We know from Vilhjalmur Stefansson's interesting books, *The Standardization of Error* (New York, 1927), and *Adventures in Error* (New York, 1936), as well as from other sources, that even scientists occasionally succumb to their own folklore. —LESLIE A. WHITE.

THE BROWNSTONE TOWER



THE editor feels that he has an obligation both to the authors of articles published in the SM and to its readers. His obligation to the authors could be met most easily by publishing their manuscripts exactly as submitted. However, if this were done, the discriminating reader would notice various inconsistencies and a wider variation in precision of expression than he would expect to find in a magazine of literary pretensions. The readers' attention to the flow of thought in an article should not be distracted by flaws in its composition. Therefore, the editor, acting as the first discriminating reader, undertakes to edit the manuscript before it is printed so that subsequent readers will not hesitate over passages that seemed questionable to him. Any changes that the editor may make should have the approval of the author before publication, and the author has the right to veto any change that is obnoxious to him.

When he edits the text of a manuscript, the editor tries to do a number of things at once. He tries to make its spelling conform with that of *Webster's International Dictionary* and its punctuation with the recommendations of *The University of Chicago Manual of Style*, not because these books are final authorities but because adherence to them makes possible an approach to the admittedly unattainable goal of consistency.

Of far greater importance in editing is the examination of each sentence to make sure that it reads smoothly and is susceptible to only one interpretation, except when a *double entendre* is intended. The editor does not hesitate to simplify clumsy sentences and to correct grammatical errors. He is also on the lookout for unnecessary repetition of words or thoughts or for obscure, irrelevant, or illogical statements and makes whatever changes or deletions are necessary to correct these faults. Summaries, which are essential in technical papers, are regarded as undesirable repetition in the SM and are deleted. Manuscripts of addresses are likely to open with pleasantries that are appropriate for a visible audience but not for the unseen reader. Suitable alterations or deletions are made in such manuscripts.

Many other editorial changes are made that have nothing to do with the quality of an article but tend to improve the appearance of the SM. For example, we believe that the cover, bearing the table of contents, looks best if the title and name of the author of each article occupy only one line. Therefore, we restrict the length of title accordingly.

We prefer that no headings be used within an article, but that a complete change of subject be indicated by a space, or white line. In some factual manuscripts a few headings may be desirable. We prefer to use side heads only, but will also use center heads if necessary.

As a rule, illustrations are reduced to column width or page width. The top of a full-page illustration is placed at the top of a page, never at the side. Contributors should bear in mind these limitations when making graphs or other line drawings for the SM. When graphs are properly proportioned and clearly marked with a lettering set, they can usually be reduced to column width, thereby saving space and improving appearance. Information about graphs should not be lettered on them but should appear in the legend.

It is our practice to use a single-line legend in large capitals, followed, if necessary, by a sublegend of one or more lines in small capitals. The length of each line of the sublegend is adjusted so that it will equal the width of a page or column. In other words, the sublegend is boxed for the sake of appearance. Unless the author cares to take the trouble to work out sublegends of the proper length, the editor will do it from the information provided by the author.

Illustrations may or may not bear figure numbers. If they do, all the figure numbers should be mentioned in the text in numerical order. The illustrations are published in that order and are placed as near the point of reference as possible.

Many contributors are known to be grateful for our editorial work on their manuscripts. It may be supposed that some are indifferent and that others are mildly annoyed. In view of the fact that the editor is not infallible and undoubtedly makes some changes that are indefensible, it is astonishing that so few protests have been received. It seems that a large majority of contributors to the SM accept in principle the desirability of editorial work on their manuscripts.—ED.